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CONTINUATION OF DEVELOPMENT AND APPLICATION OF DATA PROCESSING TECHNIQUES AND ANALYTIC PROCEDURES TO CLOUD PHYSICS DATA

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This report outlines the data collection procedures utilized in processing cloud physics data. The real time operating system on board the C130E aircraft is fully explained. Practical applications of various mathematical techniques (such as: Newton's forward formula, least square curve fitting, Pappus-Guldinus Theorem etc) are fully delineated.

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CONTENTS

PREFACE

The following personnel of Digital Programming Services, Inc. have contributed to the research reported on in this documentation

Lawrence E. Belsky

Michael W. Francis

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John E. O'Neil

1. INTRODUCTION

DPSI's contract with the Convective Cloud Physics Branch (LYC), Meteorology Division of the Air Force Geophysics Laboratory (AFGL) F19628-76-C-0051 required the company to continue the development of data processing techniques which are employed in the analysis of cloud physics data.

This report is a description of the effort expended by DPSI for AFGL(LYC) in that fulfillment. We have organized our work in sections 2 through 8 as follows:

Section 2: Additions and alterations using the PMS 1D System as a means of input

Section 3: Development of new techniques which employ the PMS 2D System as input

Section 4: Development of new techniques which utilize the LEARJET data collection system

Section 5: Alterations in the various radar programs which have been necessitated by radar hardware changes.

Section 6: Modifications of the programs for the PDP8 on board computer

Section 7: Generation of new analysis programs for the benefit of LYC scientists

Section 8: The operating instructions for the above programs.

2. PMS 1D PARTICLE SIZING SYSTEM

The one-dimensional particle sizing system on board each aircraft collects particle size distribution data for one second intervals. Data is recorded in real time using a Kennedy incremental 7 track tape recorder. These tapes are shipped to AFGL/LYC for processing and analysis. The actual details of the hardware utilized may be found in the following two reports; "Development and Application of Data Processing Techniques and Analytic Procedures to Cloud Physics Data" by DPSI, and "A Manual for the Particle Sizing Spectrometer System" by PMS Inc.

2.1 1D PROCESSOR (KNOLL1D)

Program KNOLL1D processes the one-dimensional particle data and calculates parameters such as particle number density, liquid water content, radar reflectivity, median volume diameter, and many others. This program may be run repeatedly with different particle types (ice crystals) and different processing options. KNOLL1D has a full edit capability which allows the counts of selected channels to be corrected during specified time periods. The program also produces various output files (mag tape and/or cards) to be used with additional processing programs.

This program is actually the "workhorse" of LYC. Since the nature of all the work performed is primarily research, DPSI is often required to make alterations in order to examine changes in the scientist's theories. Of course, modifications are also required from time to time because of hardware malfunctions on the aircraft.

During the past year ten separate versions of KNOLL1D have been maintained. These versions were required to meet the specific requirements of LYC personnel. Details of the basic program (v2.00) are described in a separate report entitled "KNOLL1D OPERATORS MANUAL". This report explains the different operating versions, and the required control card changes for each.

Version 2.01 was written to correct for the upper altitude pressures of flight A75-19 (15 APR 75); it should be used for this flight only. The modifications include the following:

1. $P_{cor} = 1.25*P_i - 110$

   where

   P_{cor} = corrected pressure

   P_i = calculated pressure

2. For aircraft time between 12:07:08 and 12:48:53 use

   Δp = 37.06 mb <u>FIXED</u>

Version 2.02 was written to allow processing of data with a faulty pressure sensor. This version will accept a time-height profile as part of the input deck. The height at a given time is determined by linear interpolation. The pressure is then calculated from the interpolated height using the following equation:

$$P = P_0 \left\{ 1 - \left(\frac{a}{T_0}\right) HT^{\;1/aR} \right\}$$

P_0, T_0, R and a are also input variables and are defined as follows:

P_0 = Pressure at ground

T_0 = Temperature at ground

R = Gas constant

a = Lapse rate at ground

HT = Height

Version 2.03 was written at the request of Dr. Robert M. Cunningham of the Meteorology Division, AFGL. These changes were experimental in nature and intended for flight A75-19 only. This version changed the type 2 (wet snow)

breakpoint to 5 instead of 3 for the precip probe data. Refer to the KNOLL1D OPERATORS MANUAL for a complete description of the breakpoint method used for the equivalent melted diameter determination. Similar cloud probe changes were accomplished with data cards.

Versions 2.04 and 2.05 were written simultaneously and include a complete data modification routine as requested by Dr. Robert M. Cunningham. V2.04 was necessitated to apply these modifications to the A75-19 flight. V2.05 is used for all standard flights. The goal of these modifications was, ultimately to increase the liquid water content and radar reflectivity because of certain hardware design shortcomings. The details of the techniques utilized along with examples will be found in the KNOLL1D OPERATORS MANUAL.

The justification for this modification is twofold. Firstly, there are "blind spots" associated with the 1D instrument. A blind spot may be defined as that portion of the spectra which lies between the limits of two probes.

When the instrument is measuring water droplets there is no blind spot present. However, it is the ice crystal shadow length, being reduced to equivalent melted diameter, that causes the gap. These blind spots are a function of particle type.

For example, when measuring needles the upper limit of the cloud probe is 142 microns and the lower limit of the precip probe is 241 microns, then the 1D instrument is "blind" to particles in the 142 to 241 micron range. Obviously this could have a serious effect on water content and reflectivity calculations.

Secondly, there is a design feature of the 1D system which requires modification of the data sampled. This feature is known as "end-rejection". The reason for this rejection is the philosophy of the 1D system; if the ending diode is occluded, there is no way to estimate the true particle length and it was felt, at the engineering design level, that it would be better to eliminate the particle rather than counting it as one with a lesser diameter. With that in mind, the end diode rejection feature was incorporated into the 1D system. An area of concern, however, is the number of particles being rejected; with the present 1D system there is no way to determine this. It may be of considerable consequence because the larger particles have the greatest probability of being rejected, and it is precisely these particles which will contribute heavily to the liquid water content and radar reflectivity.

Since the particle spectra is assumed to be continuous, a particle count of zero in a given channel, flanked by non zero channel counts would indicate the zero channel value is incorrect. There is a high probability that there really were particles in the zero channel, but they were rejected because the ending diode was occluded. This result will also seriously affect the water content and reflectivity calculations.

These versions (2.04 and 2.05) also allow for nine different particle types to be processed. Two of these are experimental and are used exclusively by Dr. Robert M. Cunningham. These types are designated as RMC1 and RMC2. The complete list includes the following:

type no.	particle type
1	RAIN
3	WET SNOW
5	LARGE SNOW
7	SMALL SNOW
9	BULLET-ROSETTES
11	COLUMNS (4:1)
13	NEEDLES (7.5:1)
15	RMC1
17	RMC2

Note only odd particle type numbers are specified. All even numbers are used internally within the program.

The equivalent melted diameter calculation has also been modified. This method allows two breakpoints to be specified for each particle type. The first breakpoint is specified in units of N (channel number). This controls the N′ equations:

1. $N' = m_{1j}N + b_{1j}$ for $N \leq BN_j$

   $N' = m_{2j}N + b_{2j}$ for $N > BN_j$

where

N' = adjusted channel number
N = channel number
j = particle type code
BN = channel number breakpoint
b = intercept
m = slope

The crystal size is then calculated using:

2. $CRSZ_N = Wd_p \cdot N'$

where

$CRSZ$ = crystal size (mm)

Wd_p = probe diode width (mm)

N' = adjusted channel number

After the crystal size has been determined the equivalent melted diameter is calculated for each channel using the equations:

3. $D = c_{1j} \cdot CRSZ^{e_{1j}}$ for $CRSZ \leq BC_j$

$D = c_{2j} \cdot CRSZ^{e_{2j}}$ for $CRSZ > BC_j$

where

D = equivalent melted diameter (mm)

$CRSZ$ = crystal size (mm)

BC = crystal size breakpoint

j = particle type code

c = coefficient

e = exponent

Note that steps 1 and 3 actually allow for two equations. The equation chosen is dependent upon the channel number (in step 1) or the crystal size (in step 3). Refer to the KNOLL1D OPERATORS MANUAL for all the coefficients and exponents used in these calculations. Also included are the channel number (class), adjusted channel number, crystal size (SC for scatter, CL for cloud and PR for precip), and equivalent melted diameter for each size class. The second breakpoint is specified in units of mm (shadow length).

This controls the equivalent melted diameter equation as shown in step 3. Refer to the KNOLL1D OPERATORS MANUAL for a detailed discussion of both particle typing and equivalent melted diameter calculation.

An additional parameter is also calculated in these versions. Kappa (or K) is defined as $M/\sqrt{Z}$. K is calculated four times per averaging interval; once for each probe plus the cloud and precip probes combined. In each case the average mass and average radar reflectivity are used. The plot tape produced (input to KNPLT1D) has been changed to include these four values.

In addition, to conserve space and reduce calculation time, the six moments of distribution previously calculated have been eliminated. The algorithm used in these calculations has been retained for future use, if necessary.

The RAPP tape produced (input to RAPP) has also been changed in these versions. The new format is considerably shorter and allows for more efficient processing. The new format contains 9 words per record. Items included on the new tape are: date, time, averaging interval, liquid water content (for each probe), and radar reflectivity (for each probe).

During December 1975 certain hardware modifications necessitated a change in the Kennedy tape format. This new format is summarized on the following page.

Word #	NEW	OLD
1	elapsed time	sync
17	status word (scatter)	probe configuration
33	status word (cloud)	elapsed time
49	status word (precip)	unused

A hardware change in the Knollenberg 1D system required changing the location of the elapsed time word within the tape record. In addition, the high order digit has been lost. A routine was added to this version, to recreate that high order digit.

Version 2.06 was written to accommodate these changes. This became the standard operating version for all flights after December 1975.

At the request of Dr. Robert M. Cunningham the data modification routine, used until this time, was modified and incorporated into versions 2.07 and 2.08. The changes were primarily initiated when the data of flight A76-04 (11 FEB 76) was processed. Essentially the change eliminated the entire data modification routine if there is insufficient data from the precip probe (i.e. less than two channels). Version 2.07 became the standard (from 2.06) and Version 2.08 was created from 2.02. This allowed the EDP runs (with the time-height profile) to be processed with the revised data modification routine.

Version 2.09 includes a line printer plot of median volume diameter, liquid water content, and radar reflectivity as a function of time for each pass. The parameters

are total values, i.e. cloud and precip probe combined; plotted on a logarithmic axis 81 columns long. A range of ± 4 is acceptable with a resolution of 0.1. Data outside these limits is plotted with a special character either above or below the plot.

The flowchart on the following page depicts the "evolution" of the ten versions maintained during the past year. These programs are permanently archived (with backup) and may be retrieved for processing or modification at any time.

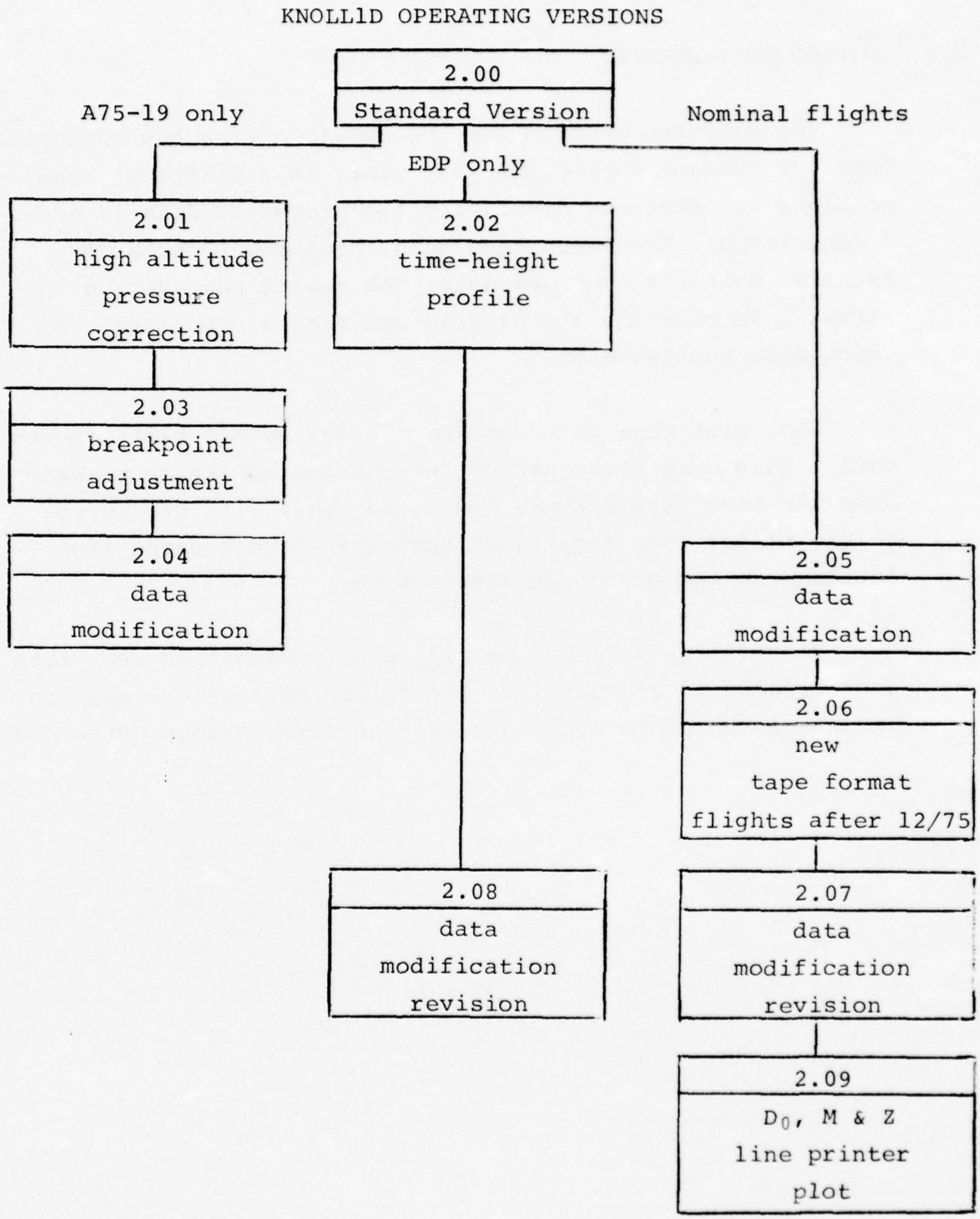


Figure 1: KNOLL1D operating versions

2.2 1D PLOTTER (KNPLT1D)

The plotting program for the PMS-1D device has undergone numerous changes during the past year. Six different types of plots are produced displaying the processed data in different forms. The input tape used, produced by program KNOLL1D, contains averaged data, one record per average interval. In addition the program can read a processed tape containing Learjet data.

Each plot tape to be produced requires one plot request card. This card contains the information necessary to produce the plot (start time, stop time etc.) with the appropriate title. The details of the plot request cards are included in the operating instructions.

To reduce plotting time and paper consumption the plots are produced on 35 mm film. The following sections explain in detail the plots available and the calculations performed.

2.2.1 Z-M scatter diagrams

This option produces two scatter diagrams of mass (M) in gms/M^3 vs. reflectivity (Z) in mm^6/m^3 on a full log scale. The first plot used precip probe data only, the second uses cloud and precip combined. Any mass value outside the range of 10^{-4} through 10^{+1} is not plotted. The reflectivity limits are 10^{-4} and 10^{+5}.

A least square logarithmic fit is calculated and drawn through the data. The equation of this line is included on the plot in the form

$$M = a\ Z^b$$

The output listing for this plot type includes the equation coefficients (both linear and exponential), the average Z and M values, with their standard deviations.

2.2.2 Z-M histograms

This option produces two histograms; the first mass (M) vs time and the second reflectivity (Z) vs time. The plots are produced using a semi-log scale. The Z and M plot limits are the same as those defined in section .2.1. The time axis is expressed in units of seconds from a given start time. These plots restrict the data to five minutes only. Any data exceeding this maximum will be ignored.

Each plot has three traces, one per probe, with a different plotting symbol used for each probe. A square indicates data from the scatter probe, a circle represents cloud data, and a triangle is used for precip data. The output listing shows only the number of points plotted per trace.

2.2.3 VCO histograms

This option produces three VCO histograms, each consisting of two lines. The VCO's plotted are: pressure, temperature, heading, dewpoint, acceleration, and J-W water content. The plots are used exclusively for system verification and are not published outside the laboratory. For this reason there is no title, pass or other identification on the plot. The time axis is similar to the Z-M histograms and also has the same five minute maximum.

The acceleration and water content plots have fixed scales; the others have a sliding scale with a fixed maximum range. The limits used for the sliding scale plots are a function of the data to be plotted. They are determined automatically by the program. Figure 2 below shows the pertinent axis information. The output listing for this plot shows only the number of points plotted.

PLOT#	VCO	UNITS	SYMBOL	AXIS TYPE	AXIS LIMITS
1	pressure acceleration	mb g	Δ +	sliding fixed	30 mb max -1 to +1
2	temperature dewpoint	deg C deg C	Δ +	sliding sliding	12° max 12° max
3	heading JW-LWC	deg gm/M^3	Δ +	sliding fixed	60° max -.1 to +.8

Figure 2: VCO Histogram Axis Information

2.2.4 Density spectra

This option produces for a selected probe six plots per page of the $\log_{10}$ of number density vs the equivalent melted diameter. The six pictures, rather than one, results from the fact that it is desired to examine this plot separately as liquid water content (LWC) increases. Thus the procedure is to first determine the combined LWC for the cloud and precip probes and determine, as a function of the LWC, which of the six plots is to be used to display the data; then the appropriate $\log_{10}$ of the number density and equivalent melted diameter is retrieved to produce the plotting points within the plot selected. The LWC limits for the six plots are defined on the plot request card.

After all this data has been plotted additional calculations are performed. These calculations, (different types of averaging) requested by Dr. Robert M. Cunningham, are shown in the following ten steps.

1. Two parameters must be calculated before the averages can be calculated.

These are ...

ICNTX(N) and
SUMX(N) for N = classes 1 to 15

where $$\text{SUMX(N)} = \sum_{i=1}^{\text{ICNTX(N)}} \text{DENSITY(N)}_i$$

ICNTX(N) = the number of samples in each class N

note: The normalized density is being used at this time also ICNTMX is the maximum ICNTX(N)

2. "INSTRUMENT LOG (AVE DENSITY)"
   Calculated for each non-zero class i.e. only if ICNTX(N)>0

```
AVEINS(N)  = SUMX(N)/ICNTMX
AVEINSL(N) = LOG (AVEINS(N))
```

3. "EXPONENTIAL LOG (AVE DENSITY)"
   a. Before this is calculated the True Ave Log Density is determined for each class where ...

$$ICNTX(N) \geq .9(ICNTMX)$$

note: JJPTS = number of classes where above relation is true

using the equations

```
AVETRU(N)  = SUMX(N)/ICNTX(N)
AVETRUL(N) = LOG (AVETRU(N))
```

   b. The set of data points (DIAM(N),AVETRUL(N)) for ICNTX(N) > 0 are linearly curvefit

note: IIPTS = number of classes where above relation is true

   c. The slope (m) and intercept (b) are printed and expressed exponentially to satisfy the equation ...

$$N/M^3\text{-mm} = N_o e^{\lambda D}$$

where $N_o = e^{2.3026(b)}$

and $\lambda = 2.3026(m)$

d. The exponential Log (AVE DENSITY) is calculated and plotted for the full spectrum (classes 1-15)

using ...

$$AVEEXP(N) = N_o e^{\lambda * DIAM(N)}$$

$$AVEEXPL(N) = LOG(AVEEXP(N))$$

where DIAM(N) = center diameter of class N

AVEEXPL(N) is printed only for classes where ICNTX(N) > 0.

4. "INSTRUMENT MASS AND REFLECTIVITY"

a. INSTRUMENT MASS

Calculated individually for each class where ICNTX(N)>0 using the instrument average density (AVEINS)

$$MINST(N) = \frac{\pi}{6} BW(N)*AVEINS(N)*DIAM(N)^3$$

where BW(N) = barwidth of class N

Also the cumulative instrument mass is calculated as

$$TMI = \sum_{N=1}^{IIPTS} MINST(N)$$

b. INSTRUMENT REFLECTIVITY

Calculated individually for each class where ICNTX(N)>0 using the instrument average density (AVEINS)

$$ZINST(N) = BW(N)*AVEINS(N)*DIAM(N)^6$$

Also the cumulative instrument reflectivity is calculated as

$$TZI = \sum_{N=1}^{IIPTS} ZINST(N)$$

5. "EXPONENTIAL MASS AND REFLECTIVITY"

a. EXPONENTIAL MASS

Calculated individually for each class where ICNTX(N)>0 using the exponential average density (AVEEXP)

$$MEXP(N) = \frac{\pi}{6} BW(N)*AVEEXP(N)*DIAM(N)^3$$

Also the cumulative instrument mass is calculated as

$$TME = \sum_{N=1}^{IIPTS} MEXP(N)$$

b. EXPONENTIAL REFLECTIVITY

Calculated individually for each class where ICNTX(N)>0 using the exponential average density (AVEEXP)

$$ZEXP(N) = BW(N)*AVEEXP(N)*DIAM(N)^6$$

Also the cumulative instrument reflectivity is calculated as

$$TZE = \sum_{N=1}^{IIPTS} ZEXP(N)$$

6. "CUMULATIVE PERCENT MASS"

$$CUMASS(N) = MINST(N)/TMI+TMASS(N-1)$$

where

$$(TMASS(N-1) = \sum_{i=1}^{N-1} CUMASS(i)$$

7. "TOTAL MASS"

To account for integration from D_i to ∞ rather than from 0 to ∞, the equation from SAMS* #2 p 58 is modified.

$$MTT = M_{(>D_1)} = \frac{\pi}{6} N_o \int_{D_1}^{\infty} D^3 e^{-\lambda D} dD$$

$$MTT = \frac{\pi}{6} N_o e^{-\lambda D_1} \left[\frac{D_1{}^3}{\lambda} + \frac{3D_1{}^2}{\lambda^2} + \frac{6D_1}{\lambda^3} + \frac{6}{\lambda^4} \right]$$

letting

$$NTT = \frac{N_o e^{-\lambda D_1}}{|\lambda|}$$

, since the slope λ should always be positive

the final equation becomes

$$MTT = \frac{\pi}{6} NTT \left[D_1{}^3 + \frac{D_1{}^2}{|\lambda|} + \frac{D_1}{|\lambda|^2} + \frac{6}{|\lambda|^3} \right]$$

If $D_1 = 0$ it can be seen that the equation is identical to that from SAMS* #2 p 58

$$MT = \frac{\pi N_o}{|\lambda|^4}$$

*Hydrometer Parameters Determined From The Radar Data of the SAMS Rain Erosion Program; Plank, V. G., (1974).

8. "TOTAL REFLECTIVITY"

To account for integration from D_1 to ∞ rather than from 0 to ∞, the equation from SAMS* #2 p 58 is modified.

$$ZTT = Z_{(>D_1)} = N_o \int_{D_1}^{\infty} D^6 e^{-\lambda D} dD$$

$$ZTT = N_o e^{-\lambda D_1} \left[\frac{D_1{}^6}{\lambda} + \frac{6D_1{}^5}{\lambda^2} + \frac{30D_1{}^4}{\lambda^3} + \frac{120D_1{}^3}{\lambda^4} + \cdots \right.$$

$$\left. \frac{360D_1{}^2}{\lambda^5} + \frac{720D_1}{\lambda^6} + \frac{720}{\lambda^7} \right]$$

letting

$$NTT = \frac{N_o e^{-\lambda D_1}}{|\lambda|}$$

the final equation becomes

$$ZTT = NTT \left[D_1{}^6 + \frac{6D_1{}^5}{|\lambda|} + \frac{30D_1{}^4}{|\lambda|^2} + \frac{120D_1{}^3}{|\lambda|^3} + \frac{360D_1{}^2}{|\lambda|^4} + \frac{720D_1}{|\lambda|^5} + \frac{720}{|\lambda|^6} \right]$$

If $D_1 = 0$ this equation also reduces to that from SAMS* #2 p 58

$$ZT = \frac{720N_o}{|\lambda|^7}$$

9. "MEDIAN VOLUME DIAMETER"
(from SAMS* #2 p 62)

$$D_o = 3.67/|\lambda|$$

---

*ibid

10. When the particle type being analyzed is rain only the total mass and total reflectivity should be integrated from D_1 to 5 mm only. This is accomplished by subtracting the 5 mm to infinity value from the D_1 to infinity value for M and Z.

a. "MASS CONSIDERATION"

$$MTT = \frac{\pi}{6} N_o \int_{D_1}^{5} D^3 e^{-\lambda D} dD = \frac{\pi}{6} N_o \left\{ \int_{D_1}^{\infty} D^3 e^{-\lambda D} dD - \int_{5}^{\infty} D^3 e^{-\lambda D} dD \right\}$$

from step 7 the D_1 to ∞ evaluation is

$$e^{-\lambda D_1} \left[\frac{D_1^{\,3}}{\lambda} + \frac{3D_1^{\,2}}{\lambda^2} + \frac{6D_1}{\lambda^3} + \frac{6}{\lambda^4} \right] = e^{-\lambda D_1} \; [\mathrm{LODM}]$$

using the same analysis the 5 mm to ∞ evaluation is

$$e^{-5\lambda} \left[\frac{5^3}{\lambda} + \frac{3 \cdot 5^2}{\lambda^2} + \frac{6 \cdot 5}{\lambda^3} + \frac{6}{\lambda^4} \right] = e^{-5\lambda} \; [\mathrm{UPDM}]$$

and finally

$$MTT_{(D_1:5)} = \frac{\pi}{6} N_o \left\{ e^{-\lambda D_1} (\mathrm{LODM}) - e^{-5\lambda} (\mathrm{UPDM}) \right\}$$

b. "REFLECTIVITY CONSIDERATION"

Repeating the previous analysis for reflectivity the final equation becomes

$$ZTT_{(D_1:5)} = N_o \{ e^{-\lambda D_1}(LODZ) - e^{-5\lambda}(UPDZ) \}$$

NTT

For parallelism NTT may be defined as:

$$NTT = N_o \{ e^{-\lambda D_1} - e^{-5\lambda} \} / \lambda$$

2.2.5 Median volume diameter plots

This option produces three different sets of scatter type plots. A set consists of two plots, each done the same way only using different data; the first plot uses precip data only and the second uses precip data combined with cloud data. The three sets are described in the following sections.

2.2.5.1 D_o vs $(Z/M)^{1/3}$

For each averaging interval this plot calculates the ratio of reflectivity to mass, and then takes its cube root. This value is checked to insure it is within the horizontal axis limits of 10^{-1} and 10^{+1}. The median volume diameter, for the same interval, is checked to insure it is within the vertical axis limits of 10^{-1} and 10^{+1}.

After the data is plotted, a least square logarithmic fit is calculated and drawn through the data. The equation of this line is included on the plot in the form

$$D_o = a((Z/M)^{1/3})^b$$

The output listing for this plot includes the equation coefficients (both linear and exponential), the average $(Z/M)^{1/3}$ and D_o values, and their standard deviations.

2.2.5.2 D_o vs $M/(Z)^{\frac{1}{2}}$

This plot is similar to the one previously discussed the only difference being the x-variable calculation. In this case the ratio of mass to square root of reflectivity is calculated. The remaining calculatons axis scales, and output are the same as the previous plot.

2.2.5.3 ND_o^4/M vs D/D_o

The calculations performed after the plot is produced were requested by Dr. Robert M. Cunningham. The procedure is a "follow-up" to the data modification technique shown in section 7.1.10. This plot differs primarily from the previous two in that it uses every non-zero channel within an averaging interval. That is, for each averaging interval as many as 15 points may be plotted. (If cloud and precip data are being used, then there may be as many as 30 points plotted per averaging interval.)

The points are plotted in the following manner. For each averaging interval the 15 (or 30) class diameters are divided by the median volume diameter. These become the x-coordinates of the plotted points. The y-coordinate is determined by multiplying the number density of each class times the fourth power of the median volume diameter. This product is then divided by the calculated mass of the interval. If the density is zero, there is, of course, no point plotted. The plot is produced on a semi-log grid, with the x-axis being linear. After all the points are plotted, a least square exponential fit is calculated and drawn through the data. The coefficients of the equation are shown on

the plot in the form

$$ND_o^4/M = a\ e^{b\ D/D_o}$$

After the plot is produced, the calculations performed are outlined below.

1. Divide the x-axis into 21 bands

2. Each point plotted is categorized by its x-coordinate into one of these bands.
   a. The y-coordinate is accumulated with other values in the same band.
   b. The number of points in each banded is counted.
   c. When all the data has been categorized and summarized, the average y value for each band is determined.

3. The bands with a zero average y value are examined. This zero results because of one of two conditions.
   a. It may be that a particular band had no points (these are called "uncounted" or type 1 zeroes).
   b. It may be that all the y-coordinate for a particular band were zero (these are called "counted" or type 2 zeroes).

4. Each type of zero may appear in two places:
   a. as a surrounded zero (or consecutive zeroes) where they are surrounded by non-zero bands on both sides.
   b. as an ending zero(or consecutive zeroes)

The following examples show both cases.

example A. surrounded zero

band#	average y	
2	1.24	
3	0	surrounded zero
4	3.94	
5	0	surrounded zeroes
6	0	
7	1.85	

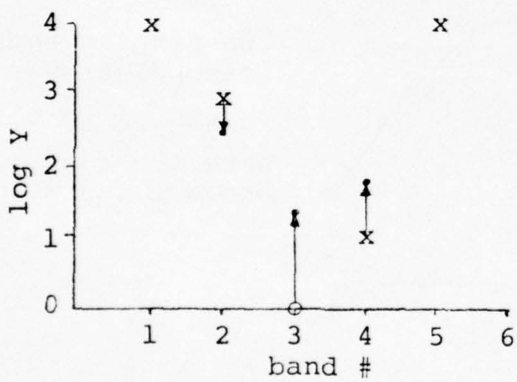
example B. ending zero

band#	average y	
1	0	ending zero
2	1.24	
3	3.28	
.		
.		
.		
18	1.29	
19	0	ending zeroes
20	0	
21	0	

5. An attempt is made to eliminate all the zeroes. The elimination technique used is dependent upon the type (1 or 2) and place (ending or surrounded) of zero. The hierarchy and technique used to eliminate these zeroes is shown on the following page.

	zero(type and place)	technique
1)	#2 surrounded	3 point running log mean
2)	#2 ending	extrapolation
3)	#1 ending	extrapolation
4)	#1 surrounded	interpolation

a. Type 2 surrounded zeroes are removed using a three point running log mean; this changes the surrounding non-zero points also.

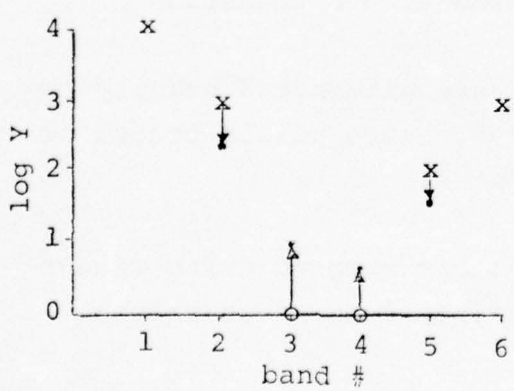


$$y_2' = (y_1+y_2+y_3)/3 = 7/3 = 2\ 1/3$$

$$y_3' = (y_2+y_3+y_4)/3 = 4/3 = 1\ 1/3$$

$$y_4' = (y_3+y_4+y_5)/3 = 5/3 = 1\ 2/3$$

o = zero point x = non-zero point



$$y_2' = (y_1+y_2+y_3)/3 = 7/3 = 2\ 1/3$$

$$y_3' = (y_2+y_3+y_4)/3 = 3/3 = 1$$

$$y_4' = (y_3+y_4+y_5)/3 = 2/3$$

$$y_5' = (y_4+y_5+y_6)/3 = 5/3 = 1\ 2/3$$

Figure 3 : Examples of type 2 surrounded zero elimination

b. Ending zeroes of types 1 and 2 are eliminated by extrapolating from the equation

$$y = ce^{[ax^2 + bx]}$$

The equation is a least square fit of four non-zero points immediately preceding or following the zeroes to be eliminated.

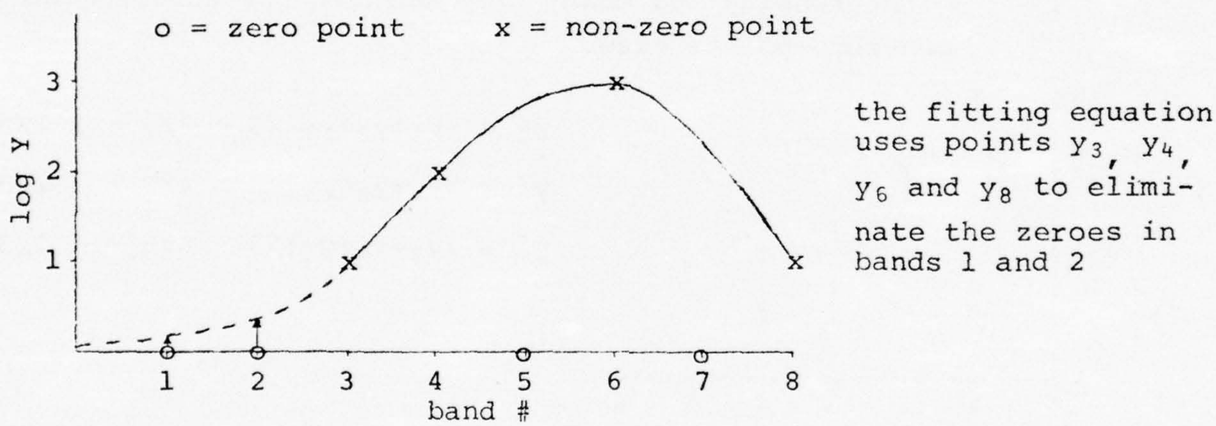
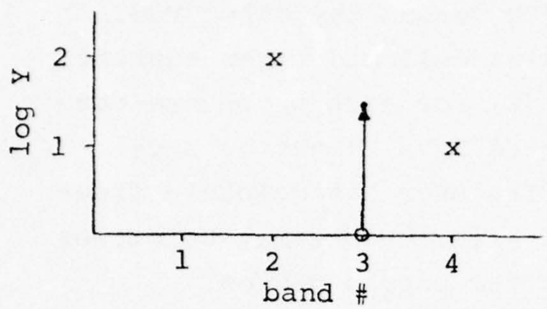


Figure 4 : Example of ending zero elimination

Zeroes at the other end are eliminated exactly the same way using the four non-zero points preceding the zeroes to be eliminated.

c. Type 1 surrounded zeroes are removed using linear interpolation between adjacent non-zero values.

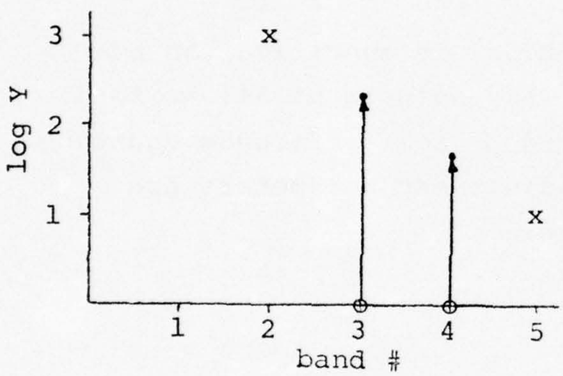


$$y_3' = y_2 + \left(\frac{y_4-y_2}{x_4-x_2}\right)(x_3-x_2)$$

$$y_3' = 2 + \left(\frac{1-2}{2}\right)(3-2)$$

$$y_3' = 2 - \tfrac{1}{2} = 1\tfrac{1}{2}$$

o = zero point   x = non-zero point



$$y_3' = y_2 + \left(\frac{y_5-y_2}{x_5-x_2}\right)(x_3-x_2)$$

$$y_3' = 3 + \left(\frac{1-3}{5-2}\right)(3-2)$$

$$y_3' = 3 - \left(\frac{2}{3}\right)1 = 2\ 1/3$$

$$y_4' = y_2 + \left(\frac{y_5-y_2}{x_5-x_2}\right)(x_4-x_2)$$

$$y_4' = 3 - \left(\frac{2}{3}\right)2 = 1\ 2/3$$

Figure 5: Examples of type 1 surrounded zero elimination

6. After the zeroes have been eliminated the results are shown in the output listing. The bands that had a zero average eliminated are flagged with a 1 or 2 indicating the type zero removed.

2.2.6 VCO plots

This option will plot any VCO versus any other VCO. With this option only, the calculated liquid water content (M) and calculated reflectivity (Z) for each probe are considered VCOs. This allows selected Z vs height or M vs height profiles to be plotted. The user has complete freedom to specify any VCO on either axis. Plots may be either in scatter mode or line mode, at the user's option.

If the plot of JW-LWC vs HEIGHT is specified, an adjustment option is available. This adjustment allows for all the data points to be shifted by some reference equation. To invoke this option certain adjustment parameters are necessary. These parameters are:

L = number of levels
XJ = origin of level
SL = slope of level
HT = height (meters)

This information is input via a namelist card as shown in the operating instructions. The adjustment performed follows.

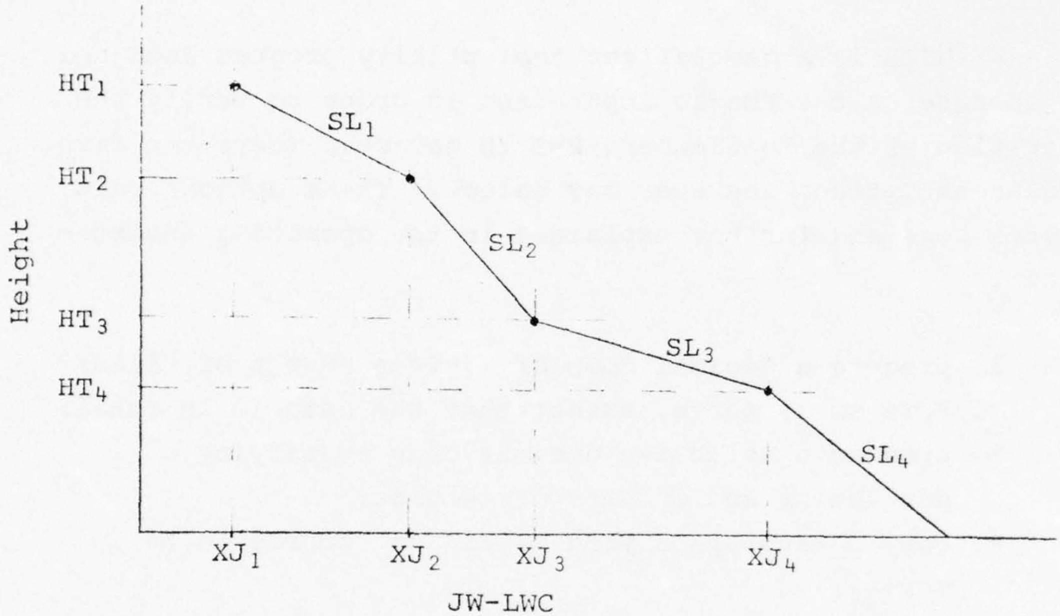


Figure 6 : JW-LWC vs height adjustment

Determine the level (I) of each data point (J,H) such that $HT_{I+1} > H > HT_I$. Calculate the adjusted water content (JW) using the equation

$$JW = J-[XJ_I + SL_I\ (HT_I-H)]$$

Note: if height (H) is greater than the maximum height (HT_1), than HT_1 is used in the equation for HT_I. The sign reversal will account for the correct JW adjustment.

2.3 PMS-1D UTILITY PROGRAM

KN1UTIL is a generalized tape utility program designed to operate on the PMS-1D input tape in order to verify the operation of the Knollenberg PMS 1D device. There are five different options the user may select. These options, are listed here and further explained in the operating instructions.

1. produce a decimal dump of a given number of files;
2. same as 1, above, except that the dump is in octal;
3. produce a selective decimal dump specifying a particular set or sets of records;
4. copy a tape specifying files and records to be copied;
5. produce a selective probe dump which will list only the channel counts of a selected probe or the VCOs.

In addition to these options, three status files are created which may be listed at the users option. These files list in an easily readable format the three status words that appear in each record.

3. PMS 2D PARTICLE DISPLAY SYSTEM

The two-dimensional (2D) particle display system on board each aircraft has some important advantages over the earlier 1D models. Firstly there are 32 sensors in each probe recording particle image data. The 1D system has 24 diodes with a maximum particle size capability of 15 classes. The cloud probe covers the size range of 25 to 800 microns; the precip probe covers 200 to 6400 microns. The second dimension is achieved by taking readings over time so that a two dimensional picture of the shadow is made. The sampling rate is adjusted to the speed of the aircraft so that a reading would be taken every 25μ of length. That is, if the aircraft flies at 100 meters/sec, the sampling rate would have to be 4 megahertz. This exact ratio can not be maintained perfectly, so the results are modified slightly in the computer according to the true air speed of the aircraft. Like the 1D device, the output is turned on when a sensor is shut off, and continues until all the sensors are back on, but this device will output the status of each of the 32 sensors every four-millionth of a second* until all the sensors are back on. Thus the 2D device gives a picture of the particle(s) as subsequent readouts are place together, and will not give incorrect results when two particles are seen simultaneously.

An additional advantage of the 2D system is the elimination of the end-rejection technique utilized in the 1D system. If a particle occludes either ending diode, it is still recorded. These particles may then be included or rejected manually with the appropriate software.

* for the Learjet this sampling rate is about 8 megahertz

The 2D particle display system is a valuable source of data to LYC. Data is collected from two independent systems (one each for the C130E and Learjet) and recorded on magnetic tape using a nine-track Pertec recorder. All the tapes are processed on the AFCRL CDC 6600 computer.

These data tapes contain two types of records, composed of "fast" and "slow" data. The fast data records contain the 2D particle image slices. One dimension, the columns, is represented by the 32 diode array, the other dimension, the rows, by time; i.e. one row represents the diode status for 250 nanoseconds of time. This is true for the C130 aircraft only; the Learjet row of data occurs every 125 nanoseconds because of the faster speed of the jet.

The slow data records occur once every ten seconds. These records contain VCO and analog information. In addition, selected 1D data is multiplexed in the 2D buffer and also recorded in the slow data records. Note that the 1D data appears redundantly (it also is being recorded by the Kennedy seven track recorder).

The exact information contained in these records is different for each aircraft. All the programs developed for this system have a variable read-in feature. That is, each program has the capability of reading the 2D tapes recorded on either aircraft.

3.1 2D PRE-PROCESSOR (TWODEE)

This program is concerned with transforming the 32 diode scans into actual particles or crystals. The technique developed uses the real time principle of a one-pass calculation; that is, while the particle is being determined certain key parameters are also being calculated. This means that after the initial pattern recognition pass, the definition of the particle is fully specified. The details of this particle definition, or "signature", are explained in the following sections.

The pattern recognition routine employs a string technique, where a string is defined as a series of consecutive occluded diodes. All the vital information required for each string is stored in one computer word, including (1) particle number or identification, (2) scan number, (3) beginning and (4) ending diode number, and (5) a linkage word. The information is stored as five 12 bit bytes within one 60 bit computer word. Routines have been written in COMPASS to insert or extract a particular byte or bytes into the computer word. Although more programming is required using this bit manipulation; it is more desirable than using 5 separate words requiring 5 times as much storage.

Each new string found is checked with strings from the previous scan. If the string is adjacent to a previous one (see figure 7) it is considered a string of the same particle. The new string identification byte must be copied from the previous string identification, thus identifying the new data as an extension of the previous. The old string linkage byte will have to be set to point to the new string word.

Two strings are considered adjacent when one of two conditions exist: (1) If two strings have at least one common diode number occluded (the left-hand example of figure 7A shows diode #6 occluded in both strings) (2) If two strings have an ending occluded diode and a beginning occluded diode within one number of each other (the right-hand example of figure 7A shows the beginning diode #3 in the first string and the ending diode #2 in the second string). In figure 7B neither condition exists, and the strings are non adjacent.

2345678	123456789
OOXXXOO	OOXXXXXOO
OOOOXXO	XXOOOOOOO

X = occluded diode
O = lighted diode

Figure 7A: Examples of non adjacent strings

As the scanning progresses certain particles will merge with others (see the stellar example in figure 8). The recognition scheme using this definition of adjacent strings accounts for this perfectly, and the particle definition information will be combined. After all 1024 scans have been examined the particles are ready for the next processing step.

OOOOOXXX	XXXOOOXXX
XXXXOOOO	OOOOXOOOO

Figure 7B: Examples of non adjacent strings

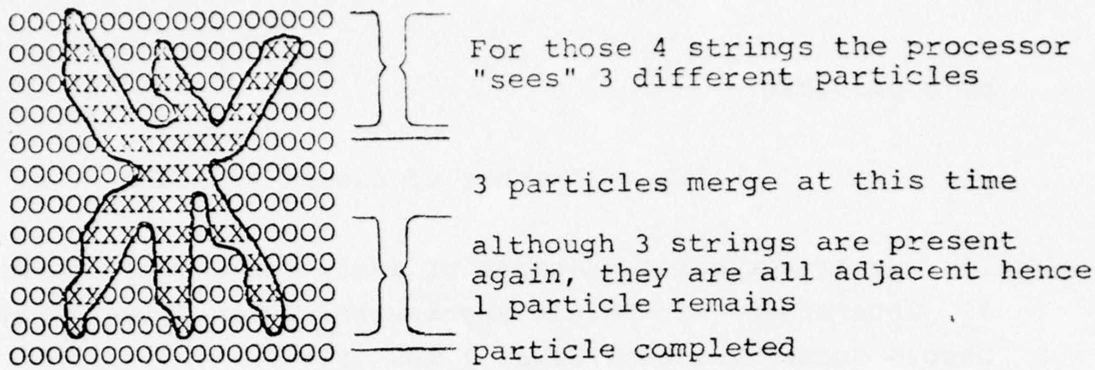


Figure 8: Particle merging

It should be noted that only completed particles are processed at this time. A completed particle is defined as a particle completely contained within the 1023 rows in the computer memory. If a particle has a contribution in the 1024th scan it is incomplete. The reasoning for this incompletion is that the particles may have additional strings in the next record. These particles are saved and if necessary merged with the next record. In either case they become the first particles processed in the next record.

A particle is said to be defined when eight fundamental parameters about it are known. These parameters are: area, perimeter, volume, horizontal projection, horizontal Feret projection, vertical projection, vertical Feret projection, and longest dimension. Five of these are either trivially calculated or a byproduct of the string technique of pattern recognition. The calculations are shown in the following paragraphs.

The area is simply the total number of diodes occluded

by a particle.

$$AREA = \sum \text{number of diodes occluded}$$

For other considerations of area, see Scientific Report #1, Determining the Volume Represented by an Irregularly Shaped Cross-sectional area, 1 Apr 75.

The perimeter is calculated as an empirical constant times twice the sum of the horizontal projection plus the vertical projection. Figure 9 compares the actual perimeter with the calculated perimeter using $K_j = 1$.

$$P = 2(HP + VP)K_j$$

where K_j = a constant for particle type j

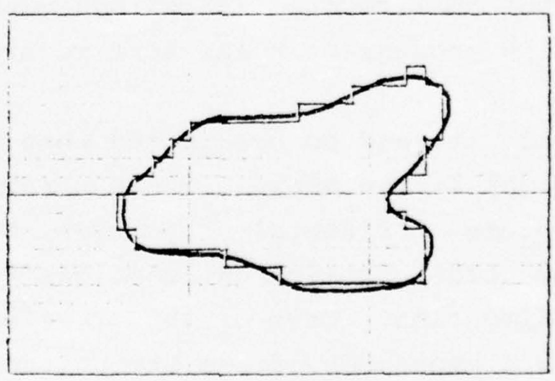


Figure 9 : Perimeter Calculation

The constant K_j should be calculated empirically since it may be too high for some particle types. Until that time

K_j should have a value of one.

Horizontal Feret projection (HFP) is the longest singular projection in the horizontal direction, i.e. the direction measured by the diode array (along the row) and not by time (along the column). This horizontal Feret projection (figure 10) is calculated by taking the largest occluded diode number less the smallest occluded diode number plus one.

$$HFP = MAX(jf) - MIN(jb) + 1$$

where jf = ending diode numbers
jb = beginning diode numbers

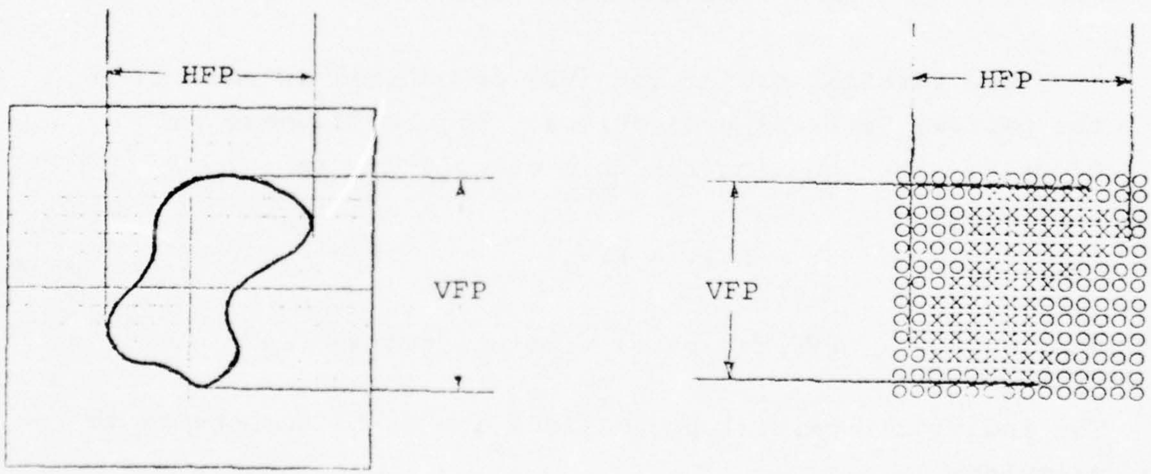


Figure 10: Horizontal and vertical Feret projection

It can be seen in figure 10 that the largest jf is 7 and the smallest jb is 2. Substitution into the HFP equation yields:

$$HFP = 13 - 2 + 1 = 12 \text{ diodes}$$

Mathematically the vertical Feret projection (VFP) is similar to HFP, the difference being the direction of measurement. Time is measured by scan number in the vertical direction. The VFP calculation is the last scan a particle appears in less the first scan a particle appears in plus one.

$$VFP = MAX(nr) - MIN(nr) + 1$$

where nr = scan number

Using figure 10 the VFP is calculated as ...

$$VFP = 12 - 2 + 1 = 11 \text{ diodes}$$

The vertical projection (VP) is defined as the sum of the partial vertical projections. Figure 11 shows this clearly. The equation for this calculation is

$$VP = PVP_1 + PVP_2$$

where PVP = partial vertical projection

The individual partial projections are quite cumbersome to calculate.

There is an easier way to calculate VP without calculating each partial vertical projection. VP can be ascertained by counting the the number of strings that make up a particle. This can be seen by the following.

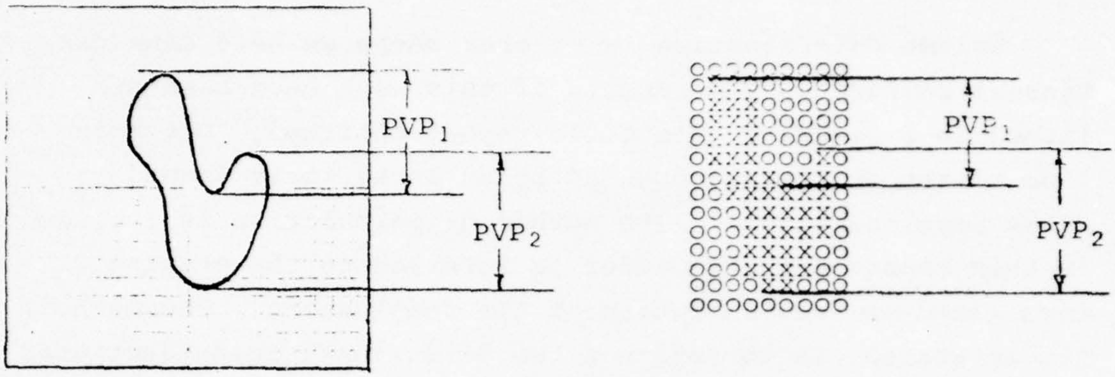


Figure 11: Vertical projection

By examination of figure 11 it can be verified that

$$PVP_1 = 6 \quad \text{and}$$
$$PVP_2 = 8$$

from this the VP is calculated by adding the partial projections:

$$VP = 6 + 8 = 14 \text{ diodes}$$

However, this is precisely the number of strings that describe this particle.

The horizontal projection (HP) is, of course, similar to the VP except for direction. A similar analysis can be performed to calculate HP. The particle is examined for strings, not in the "diode" direction, but in the "scan" direction. Again the number of strings found is precisely the horizontal projection.

Volume determination is an area where we have done extensive research. The results of this work have been published in a separate scientific report entitled, "Determination of the Volume Represented by an Irregularly Shaped Cross Sectional Area". The method of calculation is included in this report but the reader is referred to the original for a complete substantiation of the conclusions. The method, simply stated, is to rotate a two dimensional cross-sectional area about its major axis, and calculate the volume generated. A correction is made for particle irregularity by dividing the area into two halves, one above and one below the major axis. Actually each half is rotated about the major axis, and a volume is calculated for each half. The final volume is the average of the two halves.

Consider an irregular shape in 2-space, whose volume is desired:

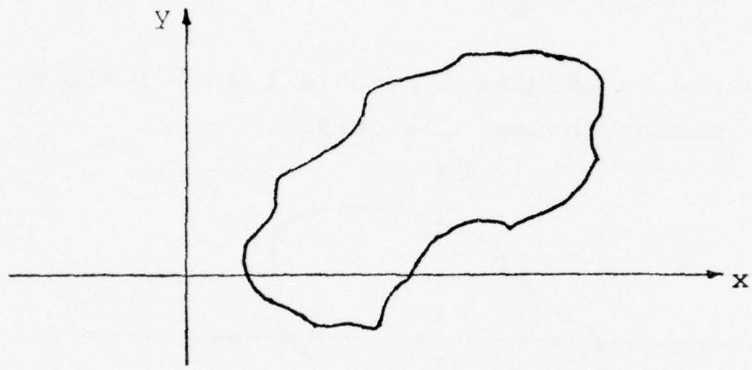


Figure 12: Irregularly shaped particle

Firstly, we translate the axes to the center of gravity of the geometric shape. Since the shape is formed by both interior and exterior points, all points are considered. The coordinates of the center of gravity (x_G, y_G) are given by

$$x_G = \sum_k x_i/N$$

$$y_G = \sum_k y_i/N$$

where x_i, y_i are the points along and inside the geometrical figure, and N is the number of x_i, y_i points.

We then form the new points X_i, Y_i given by

$$X_i = x_i - x_G$$

$$Y_i = y_i - y_G$$

Our new shape is unchanged by this transformation. The centroid now passes through the origin.

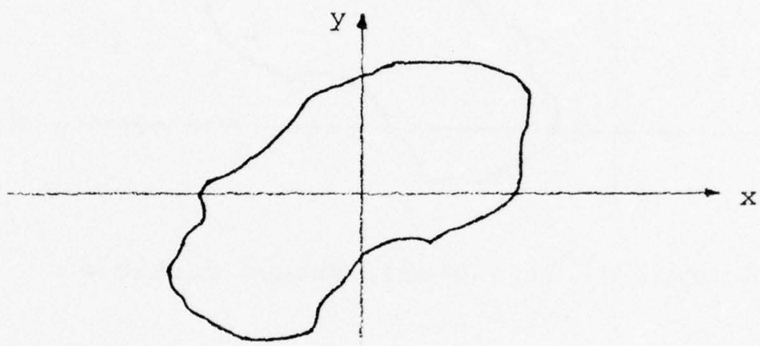


Figure 13: Origin at centroid

We now seek the major axis of the shape. This is done in order to rotate about the axis in order to find the volume. From Vector Mechanics (see Beer & Johston, STATICS AND DYNAMICS, McGraw-Hill) the moments of inertia for the shape are given by

$$I_x = \int y^2 dA$$

$$I_y = \int x^2 dA$$

$$I_{xy} = \int xy dA$$

in the discrete case, these equations become

$$I_x = \Sigma\ Y_i^2\ \Delta m$$
$$I_y = \Sigma\ X_i^2\ \Delta m$$
$$I_{xy} = \Sigma\ X_i Y_i\ \Delta m$$

I_x, I_y, I_{xy} can be computed at the same time x_G, y_G are done:

$$I_y = \sum (x_i - x_G)^2 = \Sigma\ x_i^2 - 2x_G \Sigma x_i + N x_G^2$$

Remembering that

$$\Sigma\ x_i = N x_G$$
$$= \Sigma\ x_i^2 - 2N x_G^2 + N x_G^2 = \Sigma\ x_i^2 - N x_G^2$$

Similarly

$$I_x = \Sigma\ y_i^2 - N y_G^2$$
$$I_{xy} = \sum (x_i - x_G)(y_i - y_G)$$
$$= \Sigma\ x_i y_i - x_G\ \Sigma y_i - y_G\ \Sigma x_i + N x_G y_G$$
$$= \Sigma\ x_i y_i - N x_G y_G - N x_G y_G + N x_G y_G$$
$$= \Sigma\ x_i y_i - N x_G y_G$$

thus we collect

$$S_x = \Sigma\ x_i \qquad S_y = \Sigma\ y_i$$
$$S_{x^2} = \Sigma\ x_i^2 \qquad S_{y^2} = \Sigma\ y_i^2 \qquad S_{xy} = \Sigma\ x_i y_i$$

then

$$x_G = S_x/N \qquad Y_G = S_y/N$$

$$I_y = S_{x^2} - (S_x)^2/N \qquad I_x = S_{y^2} - (S_y)^2/N$$

$$I_{xy} = S_{xy} - (S_x)(S_y)/N$$

we seek an angle of rotation θ, such that

$$u_i = X_i \cos\theta + Y_i \sin\theta$$

$$v_i = -X_i \sin\theta + Y_i \cos\theta$$

would force the new uv moment to vanish. That is

$$I_{uv} = \Sigma\, u_i v_i\, \Delta m = 0$$

$$I_{uv} = \Delta m\, \Sigma\, [X_i \cos\theta + Y_i \sin\theta][-X_i \sin\theta + Y_i \cos\theta] = 0$$

or

$$\sum (Y_i^2 - X_i^2)\, \frac{\sin 2\theta}{2} + X_i Y_i \cos 2\theta = 0$$

substituting

$$(I_x - I_y)\, \frac{\sin 2\theta}{2} + I_{xy} \cos 2\theta = 0$$

or

$$\tan 2\theta = 2\left[\frac{I_{xy}}{I_y - I_x}\right]$$

$$\theta = \tfrac{1}{2} \tan^{-1} \left[\frac{2\ I_{xy}}{I_y - I_x}\right]$$

After rotating through the angle θ, we have

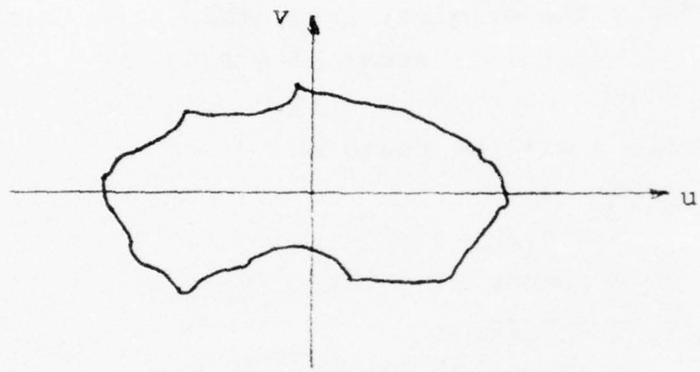


Figure 14: Particle rotated to major axes

Now in order to get the volume, we divide the area into two parts

a) all points (u_i, v_i) which lie above $v = 0$

b) all points (u_i, v_i) which lie below $v = 0$

and rotate each half about the u axis. The resulting volume will be the average of the two rotated areas.

Pappus-Guldinus second theorem states: The volume of a body of revolution equals the generating area times the distance traveled by the centroid of the area while the body is being generated.

$$V = 2\pi \bar{v} A'$$

where $\bar{v}$ = the centroid component in the v-direction

A' = area being rotated (since the u-axis bisects the original area, this area is one half ohe original area; $A' = A/2$)

each centroid $\bar{v}$ will be found as

$\bar{v}_1 = \Sigma v_i/k_1$

k_1 = number of points $\quad v_i \geq 0$

$\bar{v}_2 = \Sigma v_i/k_2$

k_2 = number of points $\quad v_i \leq 0$

and assuming the areas A_1 and A_2:

$$\text{Volume}_1 = 2\pi \bar{v}_1 A_1$$

$$\text{Volume}_2 = 2\pi \bar{v}_2 A_2$$

or

$$\text{Volume} = \pi (\bar{v}_1 A_1 + \bar{v}_2 A_2)$$

CONSIDERATION OF THE AREA

As a result of the considerations investigated in Scientific Report #1, the area is best calculated by counting occluded diodes above and below the major axis. When an occluded diode center is conincindent with the major axis, it should be counted in both halves. This report, and the scientific report assumed length dimensions of 1. That is, the distance between diodes multiplied by the distance between successive diode samplings was 1. The final Volume should be

$$\text{Volume} = \pi\ \bar{v}\ N\ (\Delta p)(\Delta x)$$

where Δp = distance between diodes
Δx = sampling distance, determined by Aircraft speed (m/sec) multiplied by time of sampling rate (sec)

CONSIDERATION OF THE ANGLE

The angle of rotation, θ, is given by

$$\theta = \tfrac{1}{2} \tan^{-1} \frac{2I_{xy}}{I_y - I_x}$$

In order to be sure that this rotation will yield the major axis (rather than the minor axis) the arctangent function will be required to produce a result between $-\pi$ and $+\pi$. If the function is limited to a range of $-\frac{\pi}{2}$ and $\frac{\pi}{2}$, the angle will have to be modified by the sign of I_{xy}.

In the former case, the resulting arctangent will be between $-\pi$ and π; Dividing this result by 2 in order to obtain θ will yield

$$-\frac{\pi}{2} < \theta < \frac{\pi}{2}$$

which is proper rotation to insure that u will be the major axis and $v = u + \pi/2$ the minor axis.

Given N points (x_i, y_i) $i = 1,2,3,\ldots,N$

compute

$$
\begin{aligned}
S_x &= \Sigma\, x_i \\
S_y &= \Sigma\, y_i \\
S_{xx} &= \Sigma\, x_i^2 \\
S_{yy} &= \Sigma\, y_i^2 \\
S_{xy} &= \Sigma\, x_i y_i \\
x_G &= S_x/N \\
y_G &= S_y/N \\
I_y &= S_{xx} - S_x^2/N \\
I_x &= S_{yy} - S_y^2/N \\
I_{xy} &= S_{xy} - S_x S_y/N \\
\theta &= \tfrac{1}{2} \tan^{-1} \left\{\frac{2\, I_{xy}}{I_y - I_x}\right\}
\end{aligned}
$$

$$c_1 = \cos\theta$$
$$c_2 = \sin\theta$$

then, for each original point (x_i, y_i)

compute

$$v_i = -c_2(x_i - x_G) + c_1(y_i - y_G)$$

and form

$$S_v = \Sigma \; |v_i|$$
$$k_1 = \text{count all } v_i \geq 0$$
$$k_2 = \text{count all } v_i \leq 0$$

then

$$\bar{v} = S_v/(k_1 + k_2)$$

note: $k_1 + k_2 \geq N$

and

$$\text{Volume} = \pi \; \bar{v} \; N$$

The longest dimension, LMAX, will be found to lie on the major axis. The volume determination, discussed in the previous section, calculates this axis as the u-axis. In addition, all the x,y particle points are transformed to u,v coordinates. The longest dimension is simply the largest u-value less the smallest u-value plus one. Mathematically this becomes

$$LMAX = MAX(u) - MIN(u) + 1$$

Pictorially this is represented as

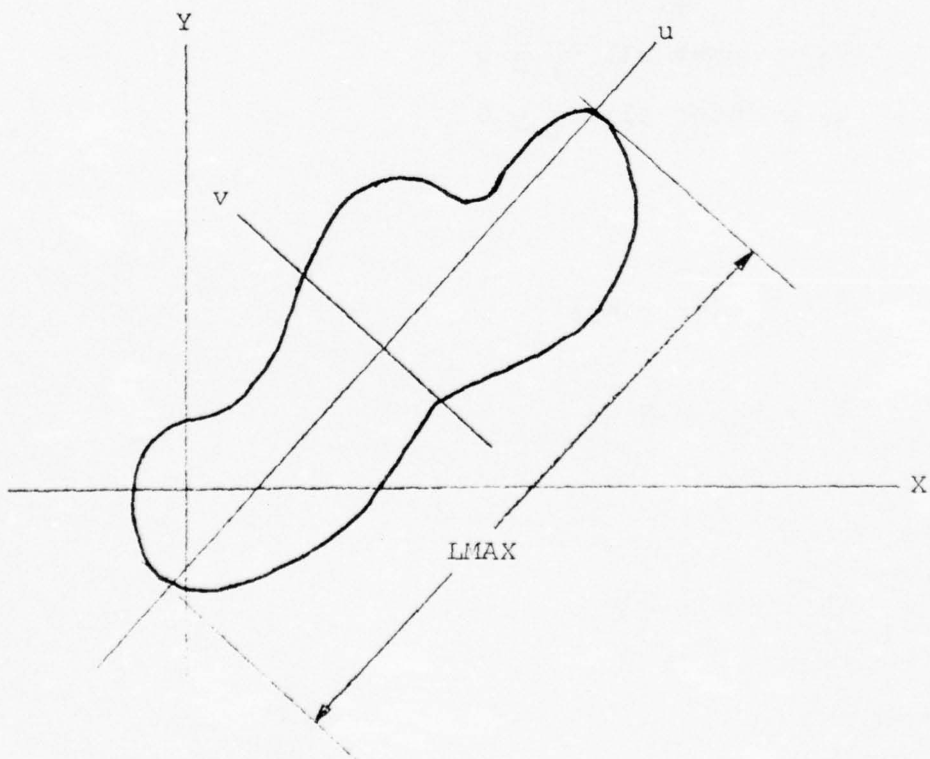


Figure 15: Longest dimension

3.2 2-D PROCESSOR (KNOLL2D)

During the past year there has been considerable progress made in this area. A preliminary version of program KNOLL2D has been completed and is currently operational. This version categorizes each particle by size class along two separate dimensions, maximum length (UMAX) and horizontal Feret projection (HFP). Each size class has a length of two diodes (i.e. 50 microns for the cloud probe and 400 microns for the precip probe). The number of observed particles in each class is summed over 1 second intervals.

Particles that touch either ending diode are differentiated from those that are completely enclosed within the 32 diode array. This requires two different counts to be maintained; one for the total number of particles, and one for the particles completely enclosed. With this technique the number of particles that would have been ignored had end-rejection been utilized becomes apparent. A sample of this output is shown on the following page. The columns labeled 'W/O ENDS' are the counts of particles NOT touching an ending diode. The counts under the column labeled 'TOTAL' include all particles.

An additional histogram is also produced; this includes particles categorized by area. Both the total and non-rejected particles are shown here also. The sample output is included on the following pages.

1 SECOND TOTAL AT 17:54:59

** C L O U D ** ** P R E C I P **

JMAX

NO.	SIZE	W/O ENDS	TOTAL	W/O ENDS	TOTAL
1	1- 2	5	5	17	23
2	3- 4	5	5	19	23
3	5- 6	4	4	17	33
4	7- 8	4	5	11	29
5	9-10	2	4	25	37
6	11-12	2	3	17	29
7	13-14	2	2	18	34
8	15-16	1	2	9	15
9	17-18	2	2	5	9
10	19-20	0	0	4	5
11	21-22	1	2	4	5
12	23-24	0	2	3	5
13	25-26	0	0	1	1
14	27-28	0	1	0	2
15	29-30	0	0	0	1
16	31-32	1	10	0	1

MED

NO.	SIZE	W/O ENDS	TOTAL	W/O ENDS	TOTAL
1	1- 2	11	14	21	40
2	3- 4	8	12	25	49
3	5- 6	4	4	15	33
4	7- 8	4	5	25	42
5	9-10	0	1	21	35
6	11-12	1	3	20	28
7	13-14	1	3	8	14
8	15-16	0	3	5	6
9	17-18	0	0	5	7
10	19-20	0	0	2	2
11	21-22	0	0	0	0
12	23-24	0	2	0	0
13	25-26	0	1	0	0
14	27-28	0	0	0	1
15	29-30	0	1	0	0
16	31-32	0	0	0	0

Figure 16: KNOLL2D Sample Output

AREA

NO.	SIZE	W/O ENDS	TOTAL	W/O ENDS	TOTAL
1	1- 20	13	23	63	108
2	21- 40	1	3	25	45
3	41- 60	3	4	20	39
4	61- 80	1	2	19	24
5	81- 100	3	3	5	12
6	101- 140	1	3	8	11
7	141- 180	0	1	5	8
8	181- 220	0	1	5	9
9	221- 260	0	2	0	1
10	261- 340	1	1	0	0
11	341- 420	0	1	0	0
12	421- 500	0	0	0	0
13	501- 660	0	1	0	0
14	661- 820	0	2	0	0
15	821-1140	0	2	0	0
16	1141-****	0	0	0	0

Figure 17: KNOLL2D Sample Output

The following tables show the actual channel sizes, (center diameter and upper and lower limits) and cross sectional area (for all particles and the non-rejected particles only) for each probe.

CLOUD PROBE

class	size (diodes)	lower limit (μ)	upper limit (μ)	center diameter (μ)	cross-sectional area: end reject (mm²)	cross-sectional area: total (mm²)
1	1 - 2	12.5 -	62.5	37.5	4.69	5.0
2	3 - 4	62.5 -	112.5	87.5	17.50	20.0
3	5 - 6	112.5 -	162.5	137.5	36.56	45.0
4	7 - 8	162.5 -	212.5	187.5	36.60	48.8
5	9 - 10	212.5 -	262.5	237.5	33.55	
6	11 - 12	262.5 -	312.5	287.5	30.50	
7	13 - 14	312.5 -	362.5	337.5	27.45	
8	15 - 16	362.5 -	412.5	387.5	24.40	
9	17 - 18	412.5 -	462.5	437.5	21.35	
10	19 - 20	462.5 -	512.5	487.5	18.30	
11	21 - 22	512.5 -	562.5	537.5	15.25	
12	23 - 24	562.5 -	612.5	587.5	12.20	
13	25 - 26	612.5 -	662.5	637.5	9.15	
14	27 - 28	662.5 -	712.5	687.5	6.10	
15	29 - 30	712.5 -	762.5	737.5	3.05	
16	31 - 32	762.5 -	812.5	787.5	0.00	

PRECIP PROBE

1	1 - 2	100 -	500	300	1536.0	1638.4
2	3 - 4	500 -	900	700	1495.2	1708.8
3	5 - 6	900 -	1300	1100	1388.4	
4	7 - 8	1300 -	1700	1500	1281.6	
5	9 - 10	1700 -	2100	1900	1174.8	
6	11 - 12	2100 -	2500	2300	1068.0	
7	13 - 14	2500 -	2900	2700	961.2	
8	15 - 16	2900 -	3300	3100	854.4	
9	17 - 18	3300 -	3700	3500	747.6	
10	19 - 20	3700 -	4100	3900	640.8	
11	21 - 22	4100 -	4500	4300	534.0	
12	23 - 24	4500 -	4900	4700	427.2	
13	25 - 26	4900 -	5300	5100	320.4	
14	27 - 28	5300 -	5700	5500	213.6	
15	29 - 30	5700 -	6100	5900	106.8	
16	31 - 32	6100 -	6500	6300	0.0	

The remaining analysis done in this program uses the particle counts with end-rejection. The reader should keep in mind that, unlike the 1D system, the number of particles ignored by this feature is readily available, by comparing the tables previously discussed.

Two new parameters have been defined and are calculated for each particle; these are 1) average projection ratio and 2) equivalent circle ratio. The average projection ratio is a measure of a particle's contour. That is, the more closely 'stellar shaped' a particle is, the higher its average projection ratio. Mathematically the formula is

$$APR = \frac{1}{2}\left(\frac{HP}{HFP} + \frac{VP}{VFP}\right)$$

where

HP and VP are total projections

and

HFP and VFP are Feret projections

The equivalent circle ratio is a measure of a particle's deviation from a circle. The equation for equivalent circle ratio ($ECR = P/\sqrt{4\pi A}$) is derived as follows:

$$ECR = \frac{P/A}{P_c/A_c}$$

where the c subscript indicates equivalent circle perimeter and area

but $A = A_c$

$$ECR = \frac{P}{P_c}$$

where $P_c = \pi D$

$$ECR = \frac{P}{\pi D}$$

but D is known so substitute:

$$A = A_c = \frac{\pi D^2}{4}$$

$$D = \frac{4A}{\pi}$$

$$ECR = \frac{P}{\pi\sqrt{\frac{4A}{\pi}}}$$

and combining

$$ECR = \frac{P}{\sqrt{4\pi A}}$$

These two parameters are categorized into sixteen size classes and the number of particles in each class is shown. The size classes for the average projection and equivalent circle ratios are shown in the following tables.

class	APR Limits		ECR Limits	
1	1.00	1.10	1.00	1.20
2	1.10	1.20	1.20	1.40
3	1.20	1.30	1.40	1.60
4	1.30	1.40	1.60	1.80
5	1.40	1.50	1.80	2.00
6	1.50	1.60	2.00	2.20
7	1.60	1.70	2.20	2.40
8	1.70	1.80	2.40	2.60
9	1.80	1.90	2.60	2.80
10	1.90	2.00	2.80	3.00
11	2.00	2.10	3.00	3.20
12	2.10	2.20	3.20	3.40
13	2.20	2.30	3.40	3.60
14	2.30	2.40	3.60	3.80
15	2.40	2.50	3.80	4.00
16	2.50	2.60	4.00	4.20

Four sets of matrices are utilized to further describe the particle distribution. The matrices display the particle counts by class size in the following manner:

1) UMAX and HFP
2) UMAX and AREA
3) UMAX and APR
4) UMAX and ECR

Each matrix is calculated twice; once for the cloud probe and once for the precip probe. Examples of these matrices are shown on the following four pages.

Another area where development has begun is in automatic particle typing. A display of the average projection and equivalent circle ratios in a common matrix provides insight into the composition of the cloud particles. This matrix is divided into sections of known particle types. The relative percentages of each particle type present are easily calculated. Examples of both the theoretical and actual matrices are shown in the following pages. In the actual case, the data collected was in predominantly rain, as borne out by the matrix display.

The programming effort described in this section is by no means complete. The work that has been detailed here is really just a beginning of the development required to glean the maximum amount of information from this data source. It is a project that will require continual modification and communication between DPSI and the LYC scientists.

UMAX AND HORIZONTAL FERET PRJ CLOUD PROBE

	01	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
01	5	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0
02	0	3	2	3	0	0	0	0	0	0	0	0	0	0	0	0
03	0	0	0	0	1	0	2	0	0	0	1	0	0	0	0	0
04	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	1
05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

UMAX AND HORIZONTAL FERET PRJ PRECIP PROBE

	01	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
01	17	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02	0	14	10	2	0	0	0	0	0	0	0	0	0	0	0	0
03	0	0	7	6	2	0	0	0	0	0	0	0	0	0	0	0
04	0	0	0	3	13	4	0	0	0	0	0	0	0	0	0	0
05	0	0	0	0	4	11	5	1	0	0	0	0	0	0	0	0
06	0	0	0	0	0	2	12	4	2	0	0	0	0	0	0	0
07	0	0	0	0	0	0	1	3	1	2	1	0	0	0	0	0
08	0	0	0	0	0	0	0	1	1	1	0	2	0	0	0	0
09	0	0	0	0	0	0	0	0	1	1	2	0	1	0	0	0
10	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 18: KNOLL2D Sample Output

UMAX AND AREA CLOUD PROBE

	01	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
01	5	5	4	4	1	0	0	0	0	0	0	0	0	0	0	0
02	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
03	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0
04	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
05	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0
06	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

UMAX AND AREA PRECIP PROBE

	01	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
01	17	18	17	8	3	0	0	0	0	0	0	0	0	0	0	0
02	0	0	0	3	15	6	0	0	0	0	0	0	0	0	0	0
03	0	0	0	0	5	8	5	0	1	0	0	0	0	0	0	0
04	0	0	0	0	0	3	11	2	2	0	0	0	0	0	0	0
05	0	0	0	0	0	0	2	2	0	1	0	0	0	0	0	0
06	0	0	0	0	0	0	0	5	2	1	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0	0	1	2	2	0	0	0	0
08	0	0	0	0	0	0	0	0	0	1	2	1	1	0	0	0
09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 19: KNOLL2D Sample Output

UMAX AND AVERAGE PROJECTION RATIO CLOUD PROBE

	01	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
01	5	4	7	4	2	2	2	1	0	0	1	0	0	0	0	0
02	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
03	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1
04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

UMAX AND AVERAGE PROJECTION RATIO PRECIP PROBE

	01	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
01	17	18	17	8	13	6	10	3	2	1	0	0	0	0	0	0
02	0	0	0	3	5	7	4	3	1	0	0	0	0	0	0	0
03	0	0	0	0	1	4	3	2	0	2	3	0	0	0	0	0
04	0	0	0	0	1	0	1	1	2	0	1	2	1	0	0	0
05	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
06	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 20: KNOLL2D Sample Output

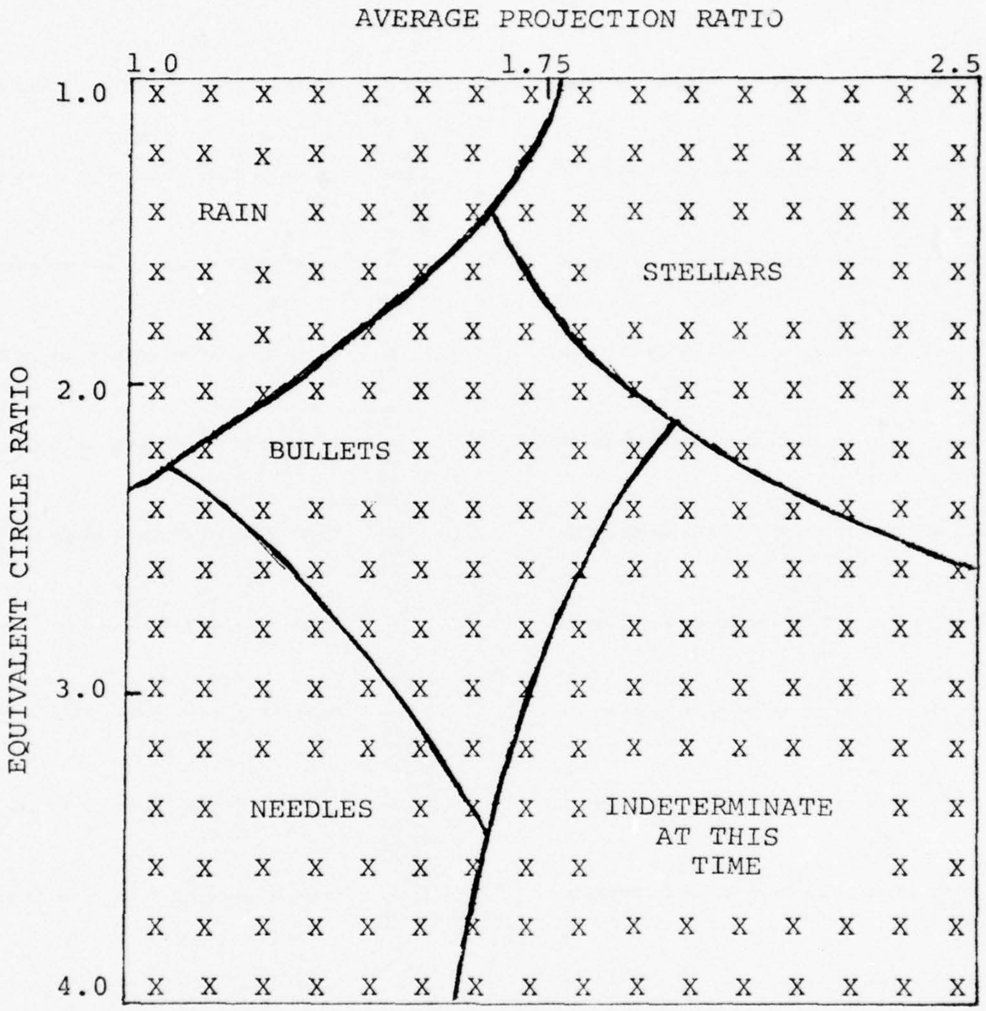
UMAX AND EQUIVALENT CIRCLE RATIO CLOUD PROBE

	01	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
01	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02	0	2	1	1	0	2	0	1	0	0	0	0	0	0	0	0
03	0	1	2	2	1	0	2	0	0	0	0	0	0	0	0	0
04	0	1	1	1	1	0	0	0	2	0	1	0	0	0	0	0
05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

UMAX AND EQUIVALENT CIRCLE RATIO PRECIP PROBE

	01	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
01	17	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
02	0	13	5	3	4	1	0	0	0	0	0	0	0	0	0	0
03	0	7	6	4	14	7	7	2	2	0	0	0	0	0	0	0
04	0	0	1	3	5	5	5	5	1	0	0	0	0	0	0	0
05	0	0	0	1	1	2	4	2	1	3	3	1	0	0	0	0
06	0	0	0	0	0	2	1	0	0	0	1	1	1	0	0	0
07	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
08	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 21: KNOLL2D Sample Output



X's = particle count in each class

Figure 22: KNOLL2D Sample Output (theoretical)

APR AND EQUIVALENT CIRCLE RATIO — CLOUD PROBE

	01	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
01	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APR AND EQUIVALENT CIRCLE RATIO — PRECIP PROBE

	01	*02*	*03*	*04*	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
01	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03	35	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0
04	13	10	4	0	0	0	0	0	0	0	0	0	0	0	0	0
05	2	4	8	4	0	0	0	0	0	0	0	0	0	0	0	0
06	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0
07	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
08	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 23: KNOLL2D Sample Output

3.3 2D UTILITY PROGRAM (KN2UTIL)

Because of the voluminous amount of data collected by the 2D particle display system, a few considerations should be made before any processing is done. For example, only data between the specified pass times should be processed. Also any data that appears faulty or even marginal should be eliminated. This program provides the verification required for these determinations. The program has been written to employ two different output media. Each output device has its own advantages and a definite place in the processing stream.

The 6600 line printer output is one means of displaying the observed particles. This printer should be utilized when there is a limited number of records to be examined, or when fast inspection of the data is vital to LYC. One might expect to get two or three of these computer runs per day using the line printer.

This limitation is due to the long record length, and it becomes impractical to print many records. Each record contains 1024 scans of the 32 diode array, yielding approximately 20 computer pages per record. A maximization scheme was developed that allows three records to be listed using 20 pages. Even with this technique to reduce output lines, a 30 record listing produces 200 pages. Therefore, although the line printer output offers faster results, its use is limited.

Another method of displaying this data is utilizing the 35 mm film plotter available at the computer center. There

are, again, advantages and disadvantages of this technique. The primary advantage of using this medium is that one full record may be displayed on a single 35 mm frame. Utilization of the film copier availabe at LYC provides any hard copies desired. In addition storage of the film rolls is much more desirable than storing cumbersome computer listings. The only drawback to this method is turn-around time. The computer center requires one full day for film processing.

To summarize, the following results are produced by this program:

1. A tape summary of all data recorded that includes
   a. record type (slow or fast)
   b. record length
   c. record number (absolute and by type)
   d. record time
2. A data listing by record type as specified
   a. slow data - line printer
   b. fast data (on selected device)
      1. line printer
      2. 35 mm film

Because the two record types are interleaved, each record to be listed may be specified in one of two ways, either by overall record number or by sequence number within type (fast or slow). If a tape consists of the following records, the record count is as shown.

	S	S	S	F	F	S	F	F	S	S	F	F	F	F	S	S	F	F	S	F
Record number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Slow sequence #	1	2	3			4			5	6					7	8			9	
Fast sequence #				1	2		3	4			5	6	7	8			9	10		11

Case A. To dump all of the above records either of the following methods should be used.

1. records 1-20

or

2. slow records 1-9

and

fast records 1-11

Case B. To dump the records indicated by the above eec-tangle use either:

1. records 8-15

or

2. slow records 5-7

and

fast records 4-8

Records to be dumped are input via a $SS card in standard namelist format. The record number technique uses prefix A; the slow record, prefix S; and the fast record prefix F. The control variable for the $SS card is REC prefixed with this character, and suffixed with a B or E indicating beginning or end of dump. For the previous two cases the $SS card should be:

Case A.

```
@$SS ARECB=1,ARECE=20 $END
            or
@$SS SRECB=1,SRECE=9,FRECB=1,FRECE=9 $END
```

Case B.

```
@$SS ARECB=8,ARECE=15 $END
            or
@$SS SRECB=5,SRECE=7,FRECB=4,FRECE=6 $END
```

where @ = blank column

4. LEARJET DATA COLLECTION SYSTEMS

LYC receives data tapes from two independent systems on board the Learjet 36C high altitude aircraft. These are: the PMS 1D particle sizing system and the PMS 2D particle display system. The 2D system is identical to that on the C130E aircraft, with the exception of a few minor VCO locations. As discussed in the previous section the current 2D programs will read and process this data without any difficulty. The PMS 1D system did require an additional programming effort.

There are two types of 1D data received at LYC; processed and unprocessed (raw). The raw data tapes have two major differences from the tapes produced on the C130 aircraft. The PMS 1D tape produced on the Learjet is 9 track, 800 bpi. Data is collected at the rate of 64 words and blocked with 32 seconds per record. (The tapes produced on the C130 aircraft also contain 64 words per second; however they are blocked with 4 seconds per record.) The word structure on the Learjet tapes consist of four 4-bit BCD characters, for a word length of 16 bits. (The C130 word structure consists of four 6-bit characters, for a word length of 24 bits.) Also the recording system utilized on the Learjet is a nine-track Kennedy 1600/360 recorder, (the C130 system uses a Kennedy seven-track tape).

With the addition of two new programs and modification of a third, the complete Learjet data collection system has been incorporated into the LYC data processing stream.

4.1 1D REFORMATTER (LEARPMS)

The processing of data is a rather complete system when the origin of the data is the C130 aircraft. Learjet data is similar to and should be analyzed in the same way as the C130 data. It is most advantageous, then, to convert the raw Learjet data to a form readable by the present 1D processing system so that the data can be analyzed as if it were from the C130. This decision has two advantages. Firstly, it eliminates many modifications to KNOLL1D which would only serve to further complicate this program. Secondly this decision provides for a backup tape to be produced. It should be noted that there is no other backup tape available from the Learjet aircraft.

Program LEARPMS has basically two functions. It will read a nine track 32 second/record tape, perform the necessary reblocking and produce a seven track 4 second/record type. When this new tape is created it will be input directly to the existing KNOLL1D program.

This program has been written and completely checked out. The program requires no input deck; it simply reads the input tape and produces a reformatted output tape, suitable for KNOLL1D processing.

4.2 1D POST PROCESSOR (HIAC1D)

The second source of Learjet 1D data LYC receives is the contractor-processed data. This is recorded on seven-track magnetic tape in IBM floating point format.

Program HIAC1D was written to read this tape; reformat the data to CDC floating point; perform basic editing, if desired; calculate the normalized particle number density; average the results over any given interval; calculate the median volume diameter for each probe; list the results in an output similar to KNOLL1D; and produce an output tape suitable for processing with program RAPP.

This output tape is identical to the RAPP tape produced by program KNOLL1D. It allows the Learjet data to be input to the Radar and Aircraft Plotting Program (RAPP see sec. 5) and correlated with the radar data received at LYC.

4.3 1D PLOTTER (KNPLT1D)

An option has been written for the standard PMS 1D plotting program (KNPLT1D) that allows this data to be plotted. When specified, this program reads the Learjet tape; performs the necessary conversions and calculations; and produces a file similar to the plot tape created in program KNOLL1D. The program then produces a set of plots similar to those produced from the data collected by the C130 aircraft.

5. RADAR DATA ANALYSIS

During each C130 data collection mission, the aircraft is tracked by a ground based weather radar facility. This radar samples the environment in a known volume of space just before the aircraft passes through it. It provides a measure of the radar reflectivity factors for the ice crystals and water droplets being observed by the aircraft.

The processing stream involved to utilize this data requires two programs to be run. The first program, SPANDAR, is a data display and reformatting program. It also produces an output tape to be used with the analysis program, RAPP. Program RAPP performs the analysis and correlations between the radar and aircraft data. Details of these two programs are shown in the following sections.

5.1 RADAR DATA DISPLAY (SPANDAR)

The radar link tapes, received at LYC, contain the meteorological information as seen by the C130 aircraft during its flight. Unfortunately these tapes are produced at the Applied Physics Laboratory in Baltimore, where an IBM installation is employed, and the data is in IBM floating point format. A program has been developed to preprocess these tapes. That is, a routine was written to convert the format from 32 bit IBM 360 floating point to 60 bit CDC 6600 floating point. The routine also converts 8 bit EBCDIC character data to 6600 display code.

During the past year the blocking algorithm utilized by APL was changed unexpectedly. To account for this, program SPANDAR had to be changed; the program now accepts any blocking format for a single tape. However, an automatic dump procedure has been incorporated into the program. If the blocking format keeps changing; the auto-dump mode is selected; the block in error is dumped hexadecimally and the program terminated. This facilitates any future changes as a result of different blocking techniques.

SPANDAR produces a tape summary that includes, for each header record, the following information: aircraft, pass, date, height, and the data start and stop times. An output tape is also produced. This tape is used as the input radar tape for program RAPP. These two functions are produced with every SPANDAR run.

The program has three additional options, selected by control cards at the users request. These include: 1) a line

printer plot of radar reflectivitiy (in DB) as a function of time and radar slant range, 2) a listing of the input tape, and 3) a punched deck.

5.2 RADAR AND AIRCRAFT DATA COMPARISON (RAPP)

Program RAPP is the means of comparing the actual liquid water content, as derived by the particle measurements obtained on the C130 aircraft, against the total mass of the observed particles, as inferred from the measured radar reflectivity. The program uses two input tapes, one containing aircraft data, the other containing radar data. The aircraft generated data is produced as an output tape from program KNOLL1D. The radar tape produced is a result of program SPANDAR. The variables of concern are time, liquid water content (mass), and radar reflectivity. Liquid water content is itself a function of the selected probe; the program will use the liquid water content for either

(1) scatter probe
(2) cloud probe
(3) precip probe
(4) total of cloud plus precip probes

A full set of plots (section 5.2.5) is produced for each pass. In addition, the radar and aircraft data is listed along with the correlation and curve fitting coefficients.

5.2.1 DATA RECONSTRUCTION

KNOLL1D outputs its aircraft data every n seconds (where n is a parameter of the program), while SPANDAR outputs data every second. In order to make a better comparison of the data, the aircraft data must be known for every second. This KNOLL1D output is the arithmetic mean of the n-point smoothed data, and reported at the beginning of every n-second time interval.

In order to reconstruct one second data, two methods come to mind (let us assume, that for the sake of this discussion, n = 4):

(a) repeat the same data for each second four times, and, by taking 3 such sets, find the least square quadratic to the 12 points; evaluate the quadratic at each second.

(b) find the quadratic exactly fitting 3 points, each of which is 4 seconds apart; evaluate the quadratic at each second.

The first method involves generation of Σx, Σx^2, Σx^3, Σx^4, Σy, Σxy, $\Sigma x^2 y$ for the equally spaced data. One could develop the matrix

$$\begin{matrix} n & \Sigma x & \Sigma x^2 \\ \Sigma x & \Sigma x^2 & \Sigma x^3 \\ \Sigma x^2 & \Sigma x^3 & \Sigma x^4 \end{matrix}$$

and get its inverse, since the x-values never change. Then multiplying this inverse by the vector

$$\begin{matrix} \Sigma y \\ \Sigma xy \\ \Sigma x^2 y \end{matrix}$$

would yield the results c, b, a in

$$y = ax^2 + bx + c$$

The second method is more easily solved, using Newton's Forward formula over the three equally spaced points:

$$y = y_0 + u(y_1 - y_0) + \frac{u(u-1)}{2}(y_2 - 2y_1 + y_0)$$

where $$u = \frac{x - x_0}{4}$$

The time variable, x, will take on the values, in seconds, from the initial time period,

$$T = .5,\ 1.5,\ 2.5,\ 3.5, \ldots,\ 11.5$$

where the values of y are known at

$$T = 2,\ 6,\ 10$$

Substituting these values in the equation, we get

$$y = y_0 + \frac{T-2}{4}(y_1 - y_0) + \left(\frac{T-2}{4}\right)\left(\frac{T-6}{4}\right)\left(\frac{y_2 - 2y_1 + y_0}{2}\right)$$

evaluating at

$$T = .5,\ 1.5$$

we get

$$y_{.5} = y_0 - .375(y_1 - y_0) + (-.375)\left(\frac{-1.375}{2}\right)(y_2 - 2y_1 + y_0)$$

$$y_{.5} = y_0 - .375(y_1 - y_0) + .2578125(y_2 - 2y_1 + y_0)$$

$$y_{.5} = 1.6328125y_0 - .890625y_1 + .2578125y_2$$

and

$$y_{1.5} = y_0 - .125(y_1 - y_0) + (-.125)\left(\frac{-1.125}{2}\right)(y_2 - 2y_1 + y_0)$$

$$y_{1.5} = y_0 - .125(y_1 - y_0) + .0703125(y_2 - 2y_1 + y_0)$$

$$y_{1.5} = 1.1953125y_0 - .265625y_1 + .0703125y_2$$

From the first two points y(.5), y(1.5), we can generate the entire set of y by a table of differences, namely

.5	$y_{.5}$		
		$\Delta y_{.5}$	
1.5	$y_{1.5}$		$\Delta^2 y_{.5}$
		$\Delta y_{1.5}$	
2.5	$y_{2.5}$		

The final column $\Delta^2 y_{.5}$ must be constant since a quadratic fits all the data, so each subsequent y can be calculated

$$y_{k+.5} = \Delta^2 y_{.5} + \Delta y_{k-1.5} + y_{k-.5}$$

let

$$\Delta^2 y_{.5} = \Delta^2, \text{ a constant}$$

$$y_{k+.5} = \Delta^2 + (y_{k-.5} - y_{k-1.5}) + y_{k-.5}$$

$$y_{k+.5} = \Delta^2 + 2y_{k-.5} - y_{k-1.5}$$

for

$$k = 2, 3, 4, 5, \ldots, 12$$

Δ^2 can be verified to be (using T = 2.5)

$$\Delta^2 = \frac{(y_0 - 2y_1 + y_2)}{16}$$

Procedure for interpolation:

1. calculate $\Delta^2 = .0625(y_0 - 2y_1 + y_2)$*

2. calculate y_1 and y_2*

$$y_1 = 1.6328125y_0 - .890625y_1 + .2578125y_2$$

$$y_2 = 1.1953125y_0 - .265625y_1 + .0703125y_2$$

3. set $k = 3$

4. evaluate

$$y_k = 2y_{k-1} - y_{k-2} + \Delta^2$$

5. increase k by 1; if $k > 12$ stop otherwise return to step 4

*note:

$$\begin{aligned} .0625 &= 1/16 \\ 1.6328125 &= 209/128 \\ .890625 &= 114/128 \\ .2578125 &= 33/128 \\ 1.1953125 &= 153/128 \\ .265625 &= 34/128 \\ .0703125 &= 9/128 \end{aligned}$$

This procedure must be compared with the least squares algorithm in order to determine the more desirable fitting technique. Three examples were performed, and referred to as examples 1, 2 and 3.

Example 1: at time = 2, y = 4
at time = 6, y = 6
at time = 10, y = 9

the computed results follow:

T	Nominal	Newton's method	Least squares
.5	4	3.5078125	3.549454
1.5	4	3.8203125	3.949051
2.5	4	4.1953125	4.380619
3.5	4	4.6328125	4.844156
4.5	6	5.1328125	5.339660
5.5	6	5.6953125	5.867132
6.5	6	6.3203125	6.426573
7.5	6	7.0078125	7.017982
8.5	9	7.7578125	7.641358
9.5	9	8.5703125	8.296703
10.5	9	9.4453125	8.984016
11.5	9	10.3828125	9.703297

Figure 24 is the comparison of these plots for example 1. The dashed line on the plot is for Newton's method; the solid for least squares. The + indicates the given, or nominal points. Correspondingly the first equation is for the Newton

Y = +.03125 X*X + .24 X + 3.375 (NEWT)

Y = +.015984 X*X +.367632 X + 3.361638 (LSQ)

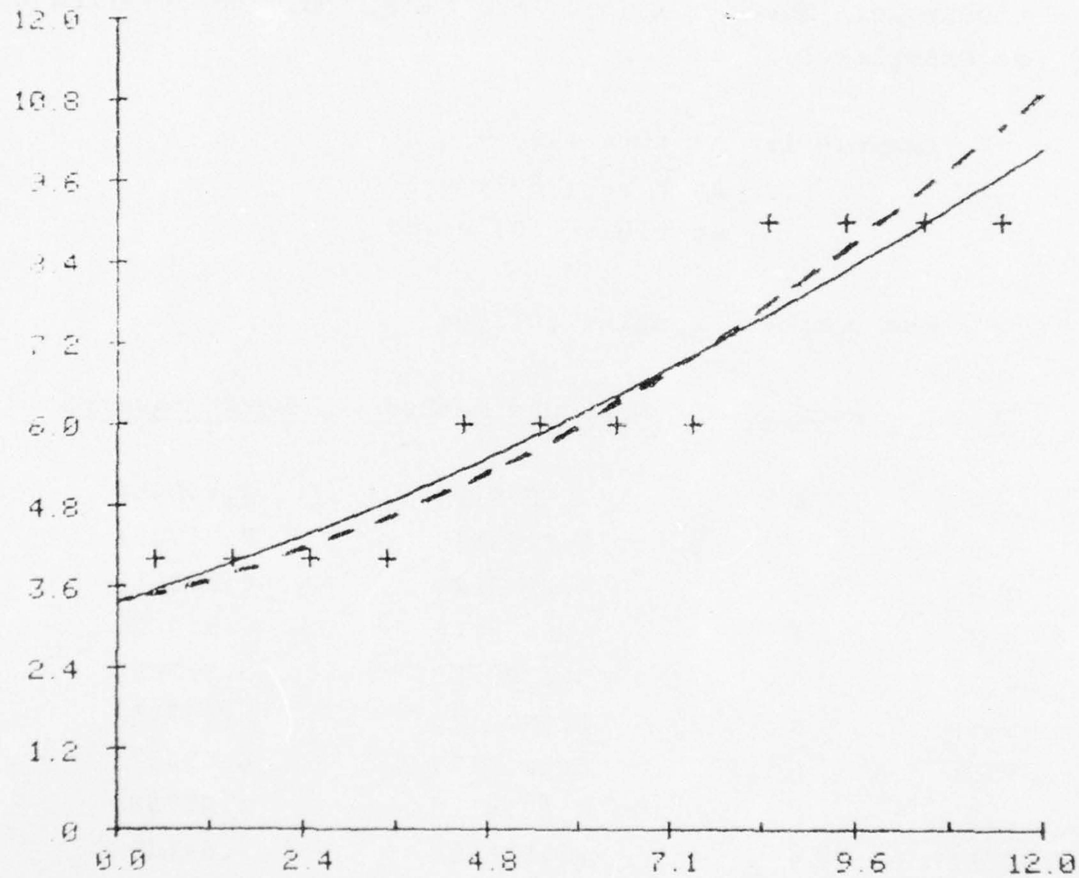


Figure 24: Example 1, points at 4,6 and 9

technique, the second equation for least squares. Note that the dashed line passes through the midpoint of the horizontal line connecting each set of four points. It appears that either curve would be satisfactory in this case.

Example 2: at time = 2, y = 4
at time = 6, y = 8
at time = 10, y = 12 (straight line)

T	Nominal	Newton's method	Least squares
.5	4	2.5	3.076923
1.5	4	3.5	3.972028
2.5	4	4.5	4.867133
3.5	4	5.5	5.762238
4.5	8	6.5	6.657343
5.5	8	7.5	7.552448
6.5	8	8.5	8.447552
7.5	8	9.5	9.342657
8.5	12	10.5	10.237760
9.5	12	11.5	11.132870
10.5	12	12.5	12.027970
11.5	12	13.5	12.923080

Again, the dashed line on the plot is for Newton's method, and the solid is for the least squares. The curves are again relatively close, and there appears to be little motivation for selecting one method in preference to the other.

Figure 25 compares these two plots.

Y = +1. X + 2. (NEWT)

Y = +.895104 X + 2.62937 (LSQ)

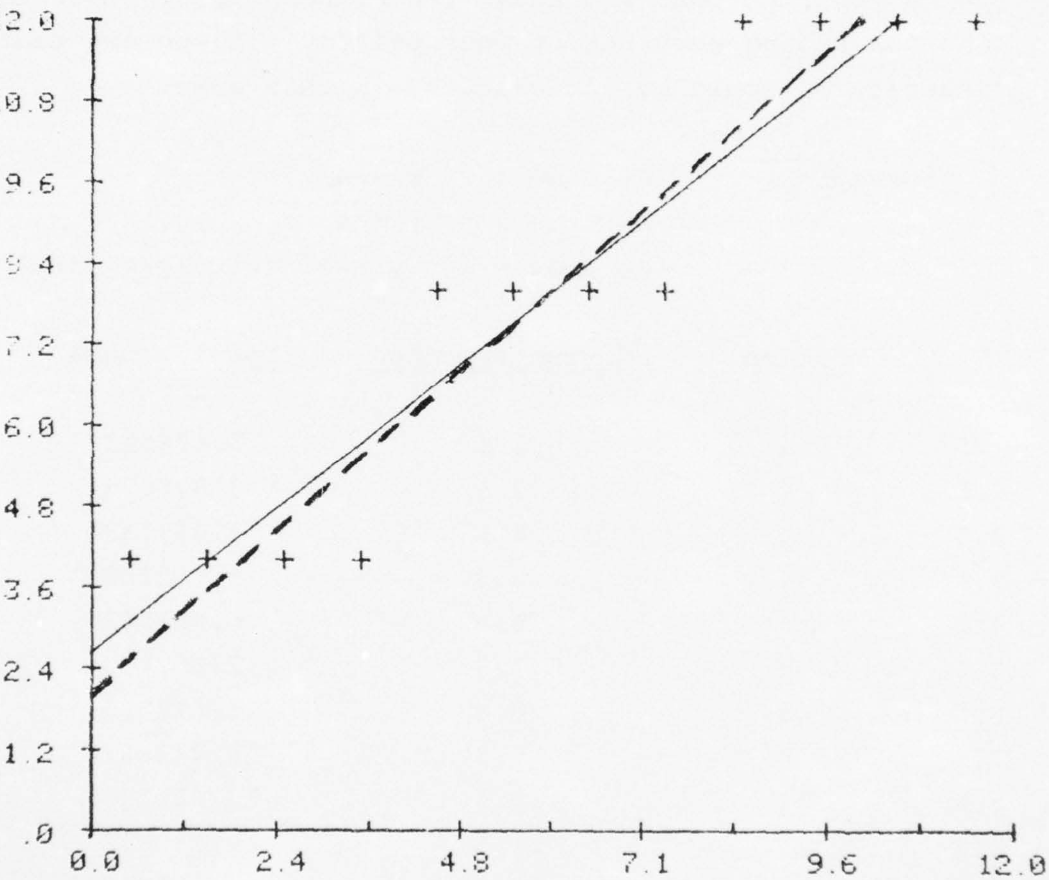


Figure 25 : Example 2, points at 4,8 and 12

Example 3: at time = 2, y = 4
at time = 6, y = 9
at time = 10, y = 6

T	Nominal	Newton's method	Least squares
.5	4	.0625	2.758242
1.5	4	2.8125	4.260740
2.5	4	5.0625	5.507492
3.5	4	6.8125	6.498501
4.5	9	8.0625	7.233766
5.5	9	8.8125	7.713286
6.5	9	9.0625	7.937062
7.5	9	8.8125	7.905094
8.5	6	8.0625	7.617382
9.5	6	6.8125	7.073926
10.5	6	5.0625	6.274725
11.5	6	2.8125	5.219781

See figure 26 for the comparison of these curves. Here we see an interesting phenomenon. The dashed line (Newton's) fits the data considerably better than the least square curve. Remembering that these given points have already been smoothed by averaging, it appears that the least square technique is smoothing even further. That is, the least square technique is smoothing out the peaks and valleys, eliminating the original character of the data.

This example leads to the conclusion that Newton's method is the more desirable tecnique. It is noteworthy that it is also easier and thus more efficient.

Y = -.24 X*X + 3.25 X - 1.4   (NEWT)

Y = -.127872 X*X + 1.758241 X + 1.911089   (LSQ)

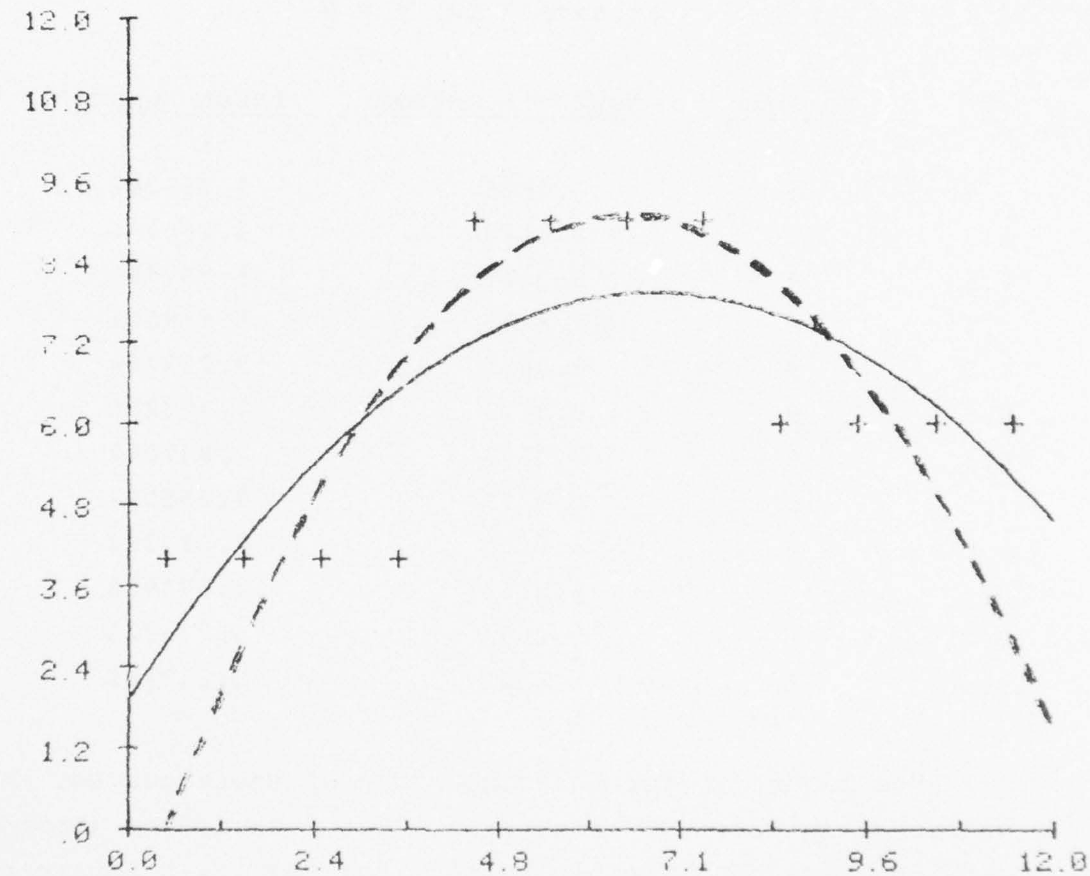


Figure 26: Example 3, points at 4,9 and 6

Although this technique works well, a recent flight (27 MAR 76) did yield erroneous data. Because the LWC and Z averages were so low, some calculated points along the curve entered the negative domain. This was, of course, unacceptable and a new technique was considered.

Newton's Forward formula, however, did work well with good data. The same technique was attempted using the logs of each point, rather than actual data. After the interpolation, antilogs were taken, and the results were, of course, always positive. This modification worked well and is currently being used. The steps used are shown below:

For three given points $(t_1,\bar{y}_1)$, $(t_2,\bar{y}_2)$, $(t_3,\bar{y}_3)$ and an average interval m

1. take logs

$$Y_1 = LOG_{10}(\bar{y}_1)$$
$$Y_2 = LOG_{10}(\bar{y}_2)$$
$$Y_3 = LOG_{10}(\bar{y}_3)$$

2. calculate Y_t for each time t, from $t = t_1-m/2$ to $t = t_3+m/2$ using ...

$$Y_t = Y_1 + (t-\frac{m}{2})[Y_2 - Y_1 + (t-\frac{3m}{2})(Y_3 - 2Y_2 + Y_1)\frac{m}{2}]/m$$

3. take antilogs

$$y_t = 10^{Y_t}$$

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5.2.2 AIRCRAFT-RADAR CORRELATION

The radar data, as has been explained, is the result of locking the signal at a fixed distance in front of the aircraft. This means that the radar time for the particular data is early, and the time has to be changed. By examining the radar data of azimuth, elevation and range, one can determine the ground speed over a desired time interval. Then one can calculate the time lag, t

$$t = d/s$$

where d is the "lock-on-distance" and s is the ground speed. This value of t is added to the reported value of t for the radar data. However, because of the nature of the radar instrumentation, there might still be a timing error of a few seconds. In order to minimize this effect, a cross-correlation is performed between the aircraft z and the radar z. This correlation is done with $\Delta t = -3, -2, -1, 0, +1, +2, +3$ and the Δt corresponding to the maximum correlation is chosen as an additional time offset.

The equations used (REF: INTRODUCTION TO MATHEMATICAL STATISTICS, Hoel, pp 117-122) is shown below.

$$r = \frac{\sum_{i=1}^{n} [(x_i - \bar{x})(y_i - y)]}{n\, S_x\, S_y}$$

where:
S = standard deviation
r = correlation coefficient

$$r = \frac{\Sigma xy - n\bar{x}\bar{y}}{\sqrt{[\Sigma x^2 - n\bar{x}^2][\Sigma y^2 - n\bar{y}^2]}}$$

$$r = \frac{n\Sigma xy - \Sigma x\Sigma y}{\sqrt{[n\Sigma x^2-(\Sigma x)^2][n\Sigma y^2-(\Sigma y)^2]}}$$

5.2.3 LEAST SQUARE CURVE FITTING

A least squares fit to the data is made for plots 1, 2 and 5 from list on page 96. Since the choice of variables for x and y is rather arbitrary, two least square lines are calculated:

$$y = ax + b$$
$$x = cy + d$$

and the RMS (root mean square) error is calculated and reported for each. The fit with the lesser RMS error is chosen as the fitting function. The formulas for the fitting functions and RMS are:

$$\bar{x} = \Sigma x/m \qquad \text{(m points)}$$
$$\bar{y} = \Sigma y/m$$

$$a = \frac{\Sigma xy - \bar{y}\Sigma x}{\Sigma x^2 - \bar{x}\Sigma x}$$

$$b = \bar{y} - a\bar{x}$$

$$c = \frac{\Sigma xy - \bar{x}\Sigma y}{\Sigma y^2 - \bar{y}\Sigma y}$$

$$d = \bar{x} - c\bar{y}$$

$$r_1 = \frac{\Sigma y^2 + a^2\Sigma x^2 - 2a\Sigma xy}{m} - b^2$$

$$r_2 = \frac{\Sigma x^2 + c^2\Sigma y^2 - 2c\Sigma xy}{m} - d^2$$

$$RMS_1 = \sqrt{r_1}$$

$$RMS_2 = \sqrt{r_2}$$

5.2.4 LEAST SQUARE FILTERING

At the request of Mr. Vernon Plank a filtering routine was added to program RAPP. The routine allows selected radar data (Z) to be omitted if it falls below the minimum detectable radar Z. This minimum detectable signal is not a constant but a function of radar slant range and a calibration constant. The equation used is as follows:

$$Z_{min}(DBZ) = DB_1 + 20\ LOG_{10}(r) + corr$$

where

DB_1 = calibration constant at 1 km

r = radar slant range (km)

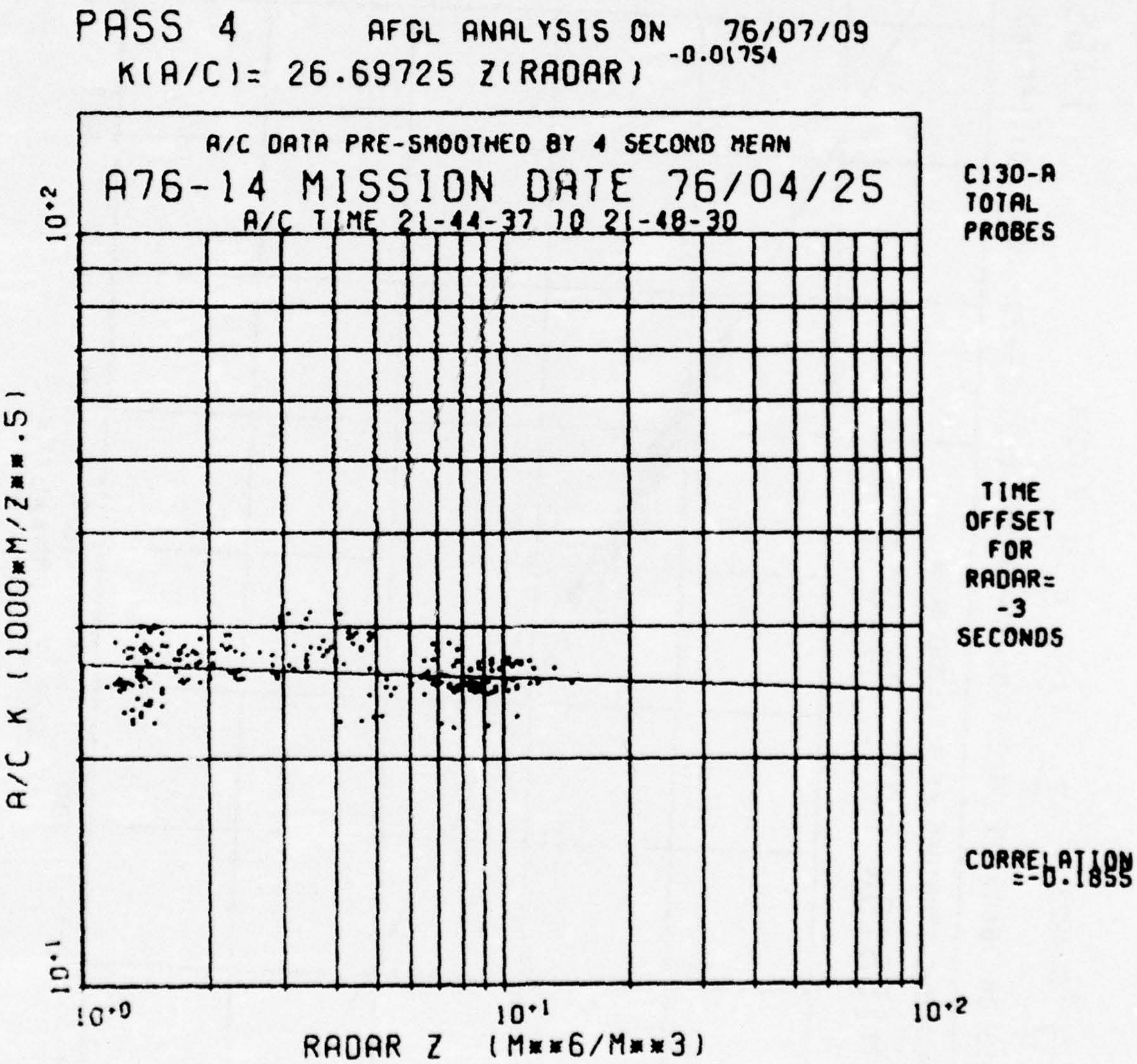
corr = particle type correction 6.5 for ice, 0.0 for water

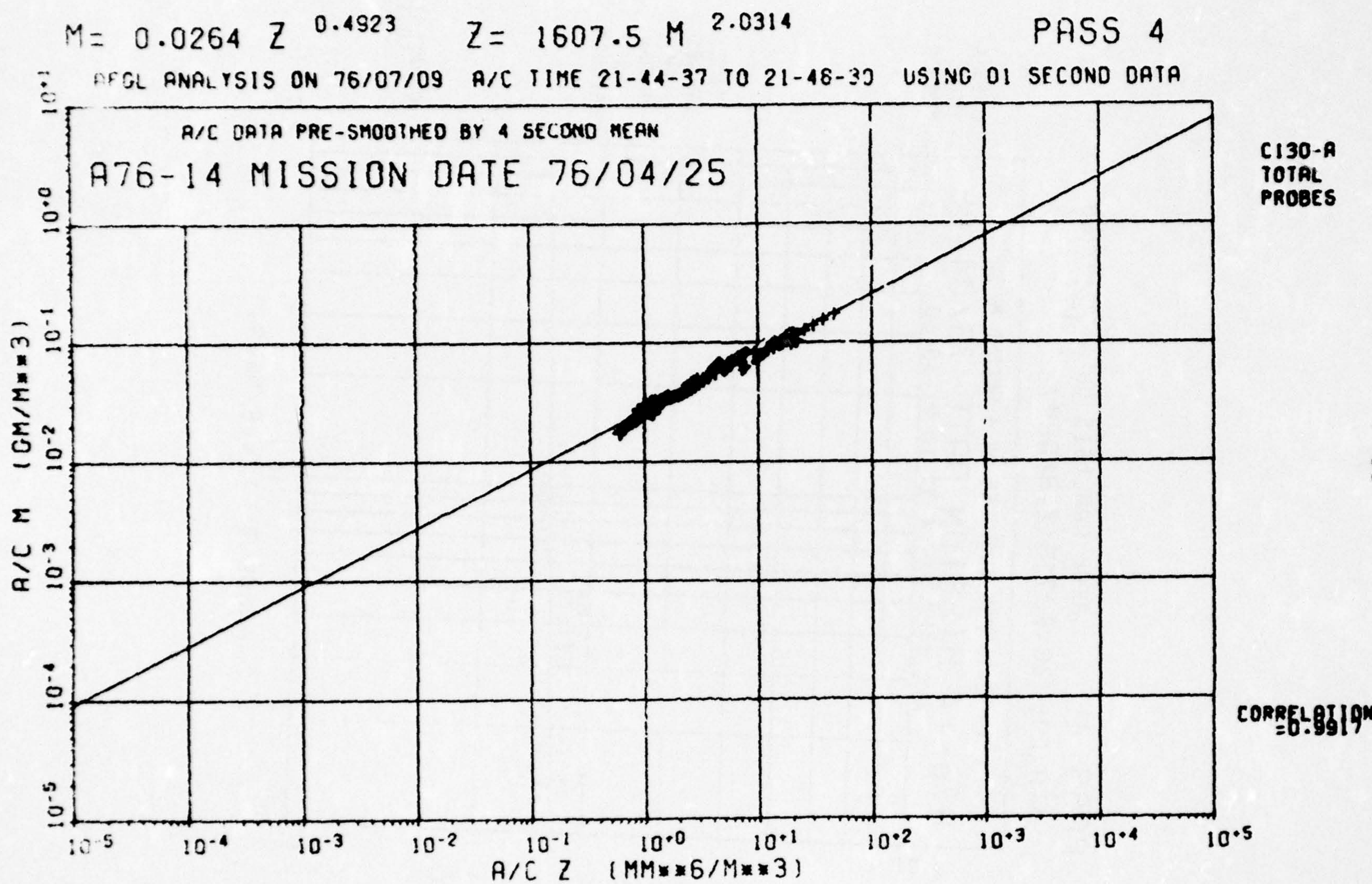
This function is also plotted on the radar Z histogram to graphically depict the data to be ignored.

5.2.5 SAMPLE PLOTS

The list of plots below are included on the following pages.

1. A/C MK ($1000*M/\sqrt{Z}$) vs. RADAR Z (Log-Log)
2. A/C M vs. A/C Z (Log-Log)
3. RADAR and A/C Z vs. TIME (Semi log)
4. A/C MK and RADAR Z vs. TIME (Semi log)
5. A/C Z vs. RADAR Z (Log-Log)
6. FLIGHT TRACK (FOR KWAJALEIN DATA ONLY)


PASS 4 AFGL ANALYSIS ON 76/07/09
K(A/C)= 26.69725 Z(RADAR) -0.01754
A/C DATA PRE-SMOOTHED BY 4 SECOND MEAN
A76-14 MISSION DATE 76/04/25
A/C TIME 21-44-37 TO 21-48-30
C130-A
TOTAL
PROBES
TIME
OFFSET
FOR
RADAR=
-3
SECONDS
CORRELATION
=-0.1855
A/C K (1000*M/Z**.5)
10+2
10+1
10+0
RADAR Z (M**6/M**3)

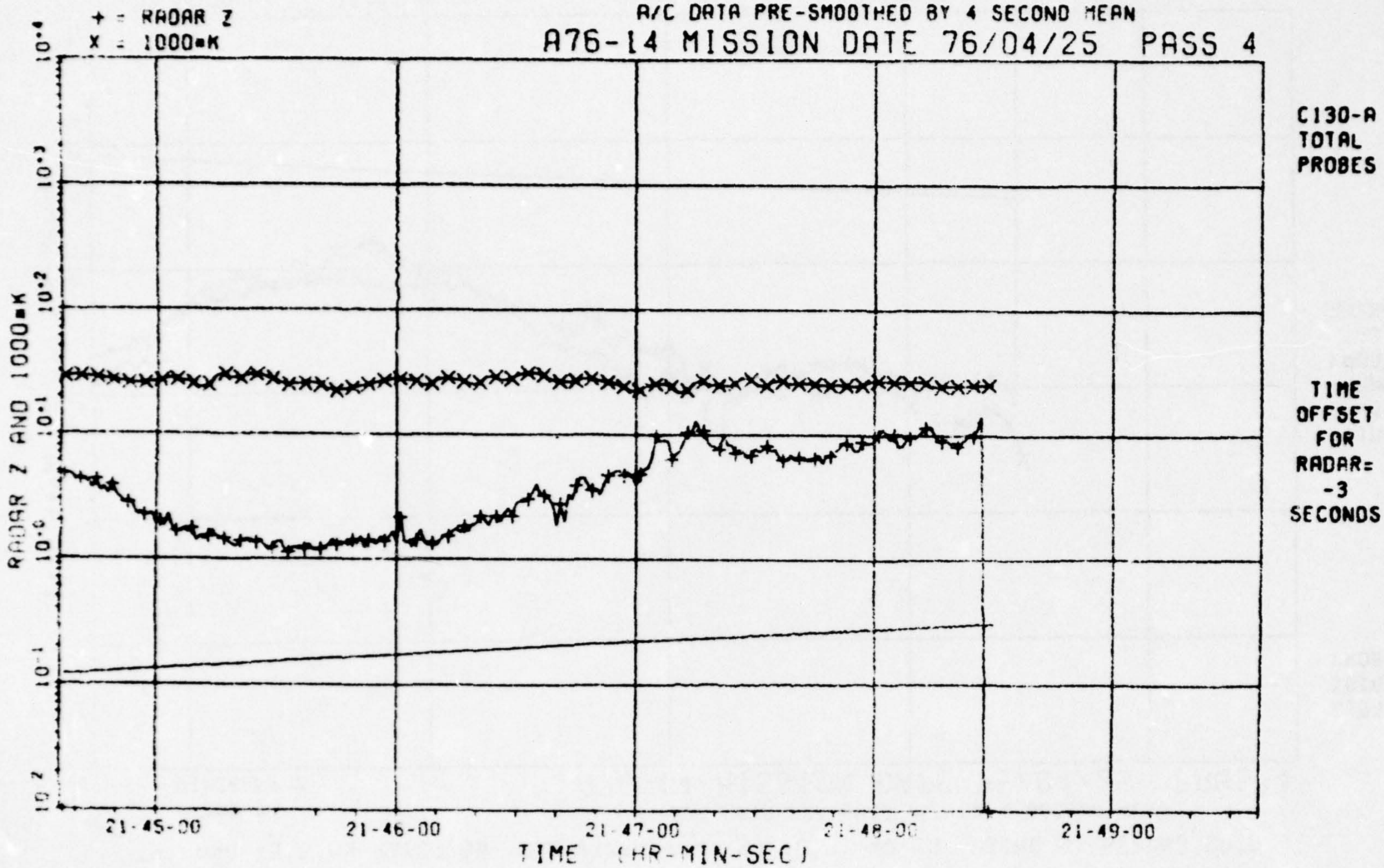


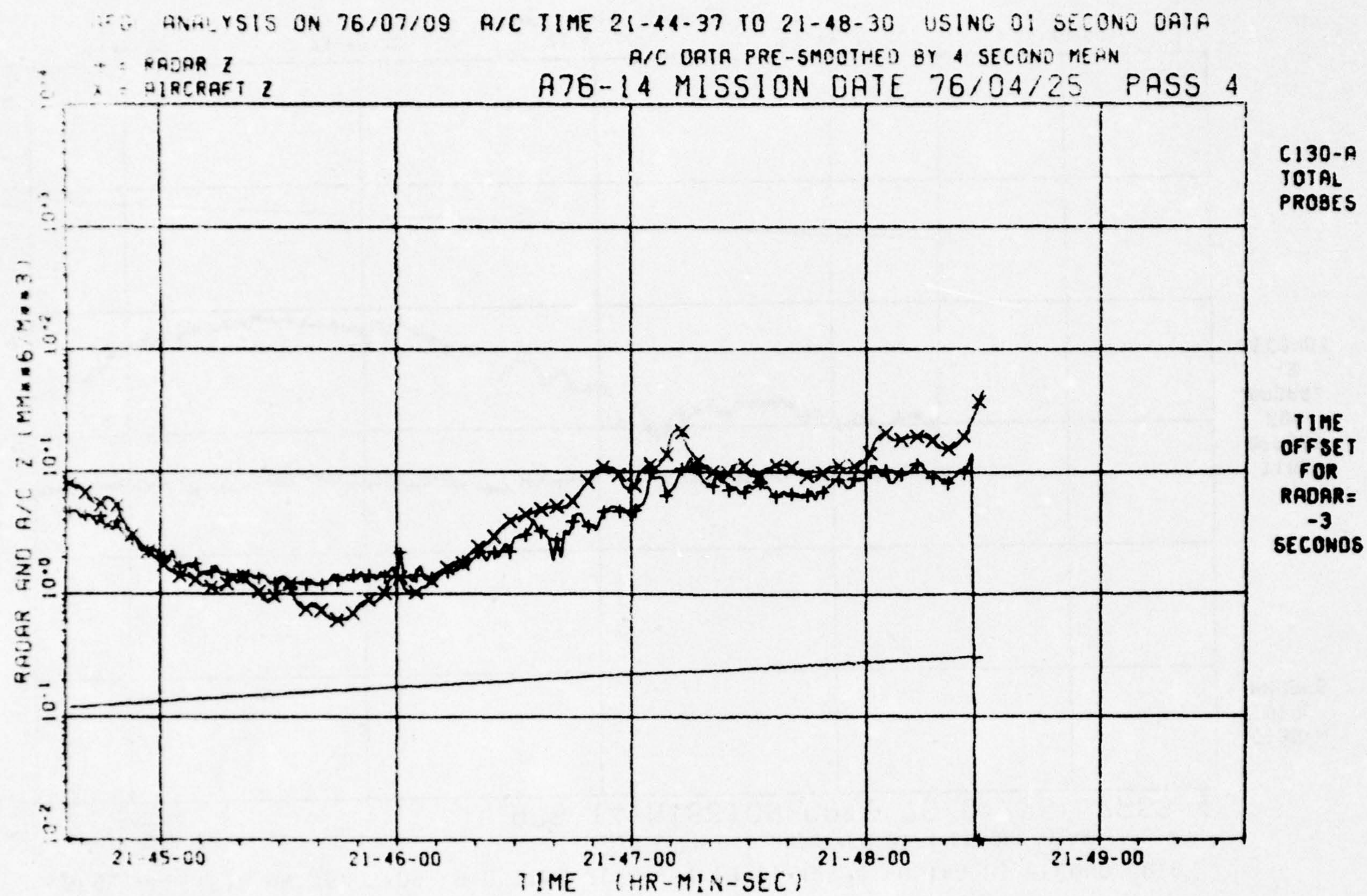
M= 0.0264 Z 0.4923
Z= 1607.5 M 2.0314
PASS 4
AFGL ANALYSIS ON 76/07/09 A/C TIME 21-44-37 TO 21-46-39 USING 01 SECOND DATA
A/C DATA PRE-SMOOTHED BY 4 SECOND MEAN
A76-14 MISSION DATE 76/04/25
C130-A
TOTAL
PROBES
CORRELATION
=0.9917
A/C M (GM/M**3)
A/C Z (MM**6/M**3)
10-5 10-4 10-3 10-2 10-1 10+0 10+1 10+2 10+3 10+4 10+5

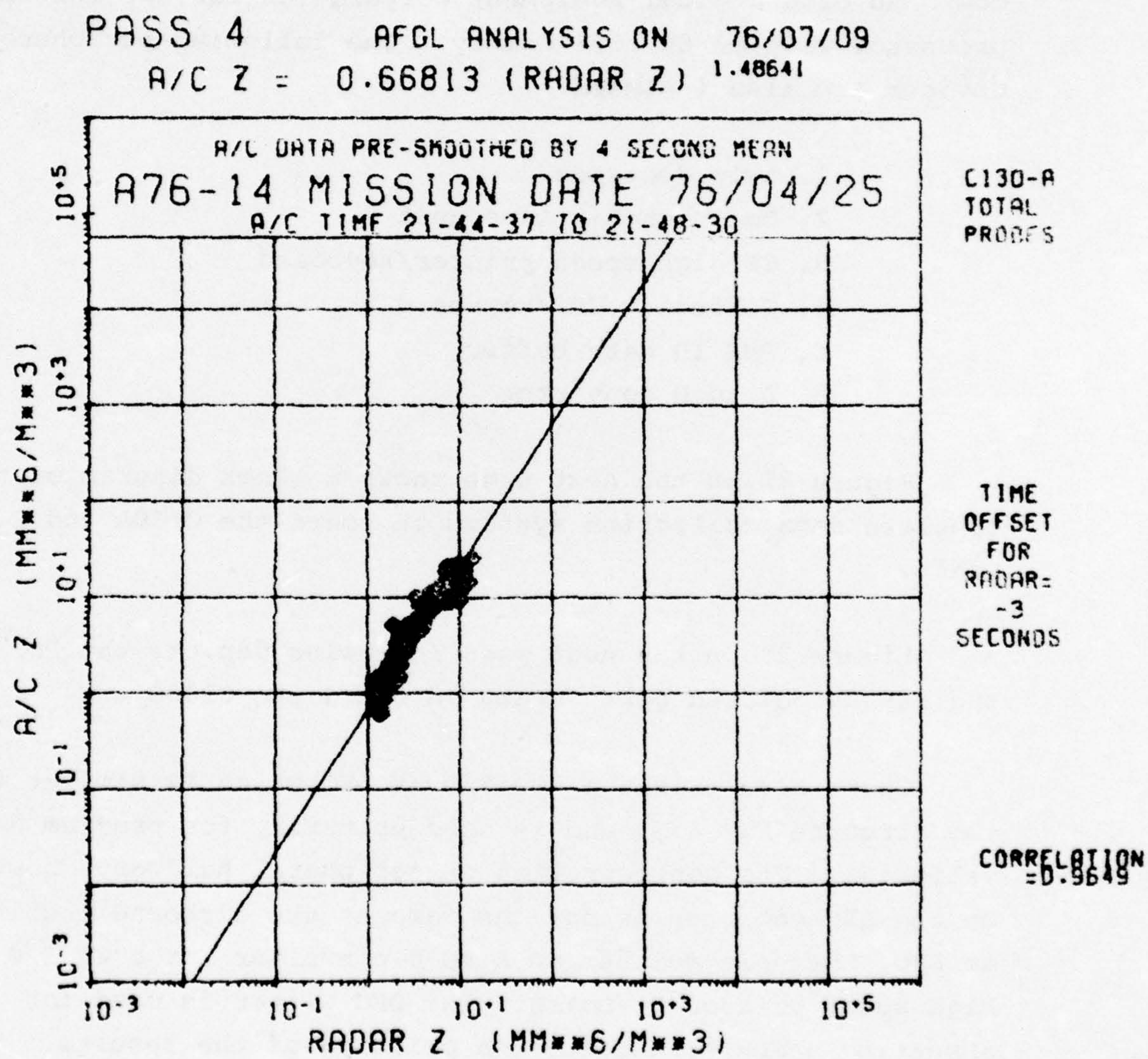
AFGL ANALYSIS ON 76/07/09 A/C TIME 21-44-37 TO 21-48-30 USING 01 SECOND DATA

A/C DATA PRE-SMOOTHED BY 4 SECOND MEAN

A76-14 MISSION DATE 76/04/25 PASS 4




ANALYSIS ON 76/07/09 A/C TIME 21-44-37 TO 21-48-30 USING 01 SECOND DATA
A/C DATA PRE-SMOOTHED BY 4 SECOND MEAN
+ = RADAR Z
X = AIRCRAFT Z
A76-14 MISSION DATE 76/04/25 PASS 4
C130-A
TOTAL
PROBES
TIME
OFFSET
FOR
RADAR=
-3
SECONDS
RADAR AND A/C Z (MM**6/M**3)
10⁻²
10⁻¹
10⁰
10¹
10²
10³
21-45-00
21-46-00
21-47-00
21-48-00
21-49-00
TIME (HR-MIN-SEC)


PASS 4 AFGL ANALYSIS ON 76/07/09
A/C Z = 0.66813 (RADAR Z) 1.48641
A/C DATA PRE-SMOOTHED BY 4 SECOND MEAN
A76-14 MISSION DATE 76/04/25
A/C TIME 21-44-37 TO 21-48-30
C130-A
TOTAL
PROBES
TIME
OFFSET
FOR
RADAR=
-3
SECONDS
CORRELATION
=0.9649
A/C Z (MM**6/M**3)
10+5
10+3
10+1
10-1
10-3
10-3
10-1
10+1
10+3
10+5
RADAR Z (MM**6/M**3)

6. AIRBORNE DATA COLLECTION SYSTEM

The airborne data collection system utilized by LYC is composed of a Digital Equipment Corporation PDP 8/E central processor with an 8K core memory. The following peripheral devices are also included:

1. twin dectapes
2. Dec magnetic tape unit
3. GE high speed printer/keyboard
4. Tektronix CRT/keyboard
5. PMS 1D data buffer
6. A to D converter

Figure 27 on the next page shows a block diagram of the complete data collection systems on board the C130A and E aircraft.

Figure 28 on the next page following depicts the PDP 8/E and its associated peripherals on board the C130E.

There also exists a PDP 8/E at LYC which is similar to the airborne PDP 8/E, and is used primarily for program development. The configuration of peripheral hardware, however, on the LYC computer is not the same as the airborne machine. At LYC, there is neither an A to D converter nor a GE I/O High speed printer/keyboard. The DEC writer is used for inputting numbers, and for the printing of the results. Thus no VCO or hard-wired input comes into the computer directly. At LYC, inputs which are necessary for debugging are simulated by patch boards, or the reading of output tapes back into the computer.

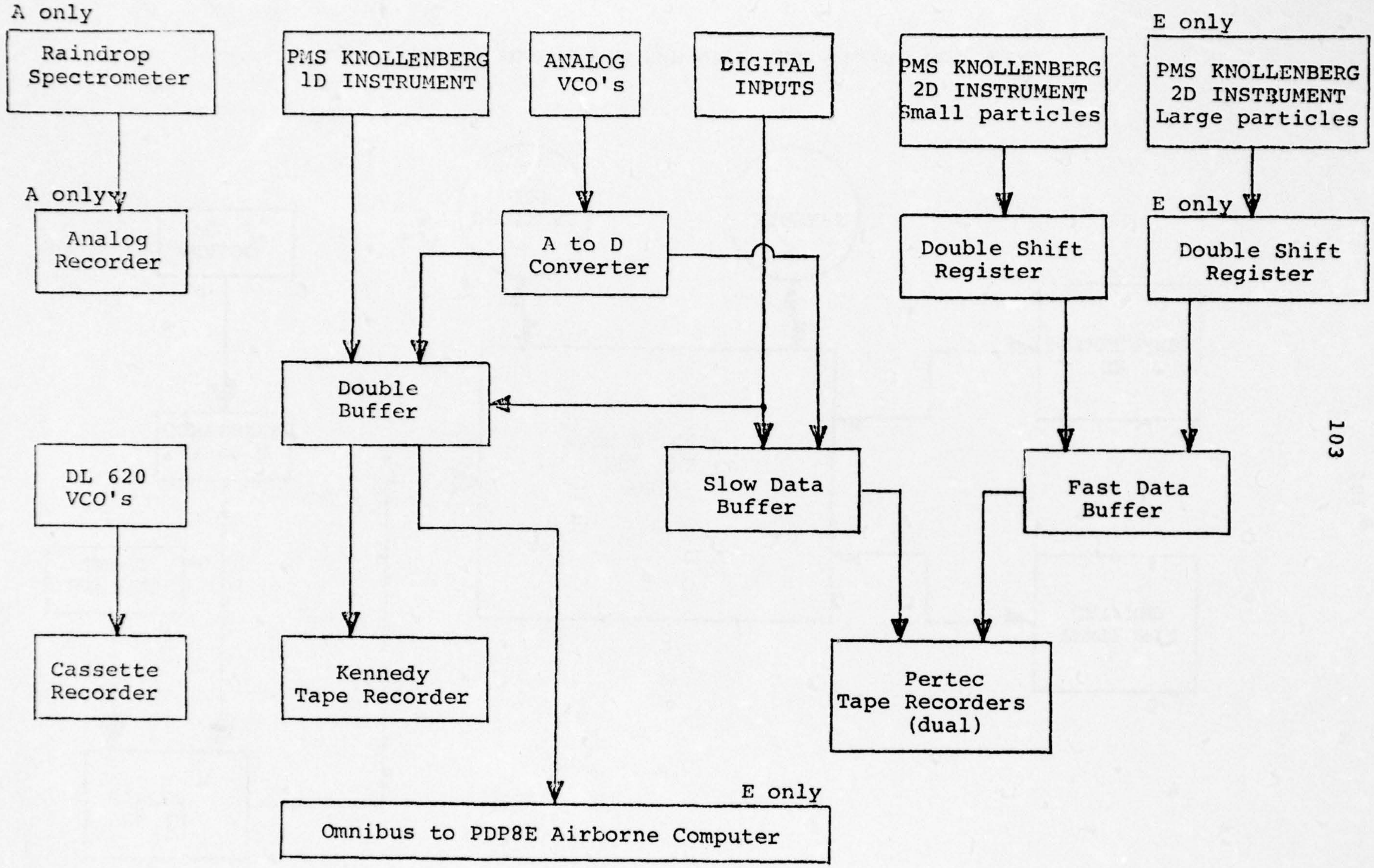


Figure 27: Data flow on the C130A and C130E aircraft

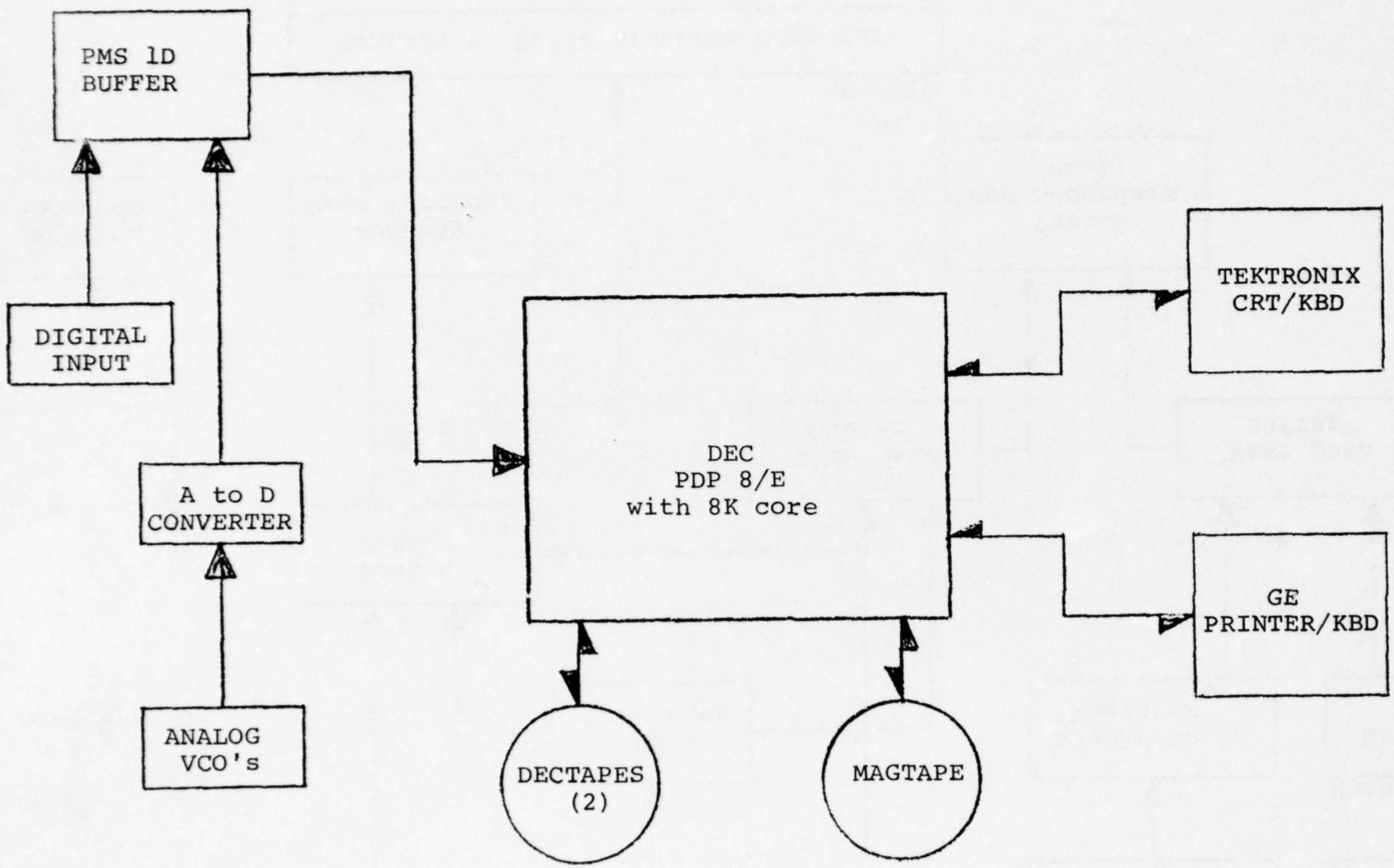


Figure 28: Airborne PDP 8/E with Associated Peripherals

In addition, there are significant differences in the IOT (input-output transfer) commands. The IOT's are the commands the programmer uses in order to obtain, make ready or output parameters from or to core locations. The reader should note that certain IOT's are not available on the LYC computer (PMS and VCO inputs). More importantly, the programmer is cautioned that a particular IOT will execute quite differently on the two computers. Also, both computers use the same IOT's for the magnetic tape device.

The processing performed on the airborne computer is divided into two parts: the first is the collection of data while the flight is taking place, and the monitoring of that data. *This first part is called the real time analysis.* The second use of the airborne computer is referred to as post flight processing and is really a data verification printout.

6.1 DEC PDP8/E OPERATION

This section describes the procedures used to bootstrap the computer and start up the OS/8 operating system. OS/8 is used to call out programs for execution such as, RTS8, QWIKY, etc. The procedures for mounting and dismounting magnetic tapes are also described.

Bootstraping the Computer

press down HALT and pull back up
Dial in one DECtape unit as '0' (zero), the other as '1'
REMOTE/OFF/LOCAL - OFF
WRITE ENABLE/WRITE LOCK - WRITE LOCK
Mount current system tape on unit zero
Thread tape onto take up reel
REMOTE/OFF/LOCAL - LOCAL
'→' press until tape is secure on take up reel
REMOTE/OFF/LOCAL - REMOTE (REMOTE SELECT Light should come on)
set SR (switch register) to 7470
press LOAD ADDRESS, EXTD ADDR LOAD, CLEAR, CONTINUE
the hardware ROM will now cause OS/8 to be loaded into core and started
the computer should print a dot (.) on the Tektronix to signify that the OS/8 is running and is ready to accept commands

Mounting and Dismounting Magnetic Tapes

The first step in mounting a tape is deciding whether or not a write enable ring should be used. The write enable ring should be used if the tape is being mounted prior to running, RTS/8 for a data collection mission. The ring should not be used when running QWIKY, IBOL or any program which retrieves data already on the tape.

Next, the following steps should be followed to mount the tape

turn transport on
LOAD/BR REL - LOAD
ON LINE/OFF LINE - OFF LINE
START/STOP - STOP
FWD/REW/REV - FWD
START/STOP - START
the tape should now advance to the load point and the LOAD
  POINT light should come on
UNIT SELECT - 0
ON LINE/OFF LINE - ON LINE (SEL and RDY lights should come on)
the tape is now ready for use

To dismount tapes use the following procedure

ON LINE/OFF LINE - OFF LINE
START/STOP - STOP
FWD/REW/REV - REW
START/STOP - START
tape should rewind and position itself at the load point
  (LOAD POINT light will come on)
LOAD/BR REL - BR REL
the tape should now be spun off by hand

6.2 REAL TIME SYSTEM RTS/8

The real time data collection system consists of a monitor (RTS/8) capable of managing a multi-task environment and several tasks which run under control of this monitor. The operator may selectively run and halt these tasks as desired. The primary task which runs under RTS/8 is the TAPE program which records all pertinent data onto magnetic tape. The usefulness of the RTS/8 monitor lies in the fact that it allows programs to run real time in a multi-task environment, that is, tasks may respond to external stimuli and run at the same time.

The RTS/8 monitor is the heart of the data collection system. Programs TAPE and LWCD are run under control of this monitor. To run RTS/8 the following procedure should be followed

TEKTRONIX R4010
  POWER - ON
  LOCAL/LINE - LINE
  PAGE - press after screen lights up
HARD COPIER 4610
  POWER - ON
Select a magnetic tape with the write enable ring in to be used to record the flight data
Mount the tape on the TU10 (refer to section 1.2 for a description of this procedure)
Bootstrap the computer (refer to section 1.1 for a description of this procedure) and respond to the OS/8 dot by typing .R RTS8
The system should print an asterisk (*) on the Tektronix to signify that RTS/8 is running and ready to accept commands

RTS/8 will accept the following commands at the command level (signified by the asterisk printout)

ON,name	activate user program "name"
OFF,name	de-activate user program "name"

To get to command level strike a character while RTS/8 is running

To terminate data collection operations push the HALT switch on the computer and dismount the magnetic tape from the TU10 (refer to section 1.2 for a description of this procedure)

6.2.1 Program TAPE

The TAPE program is the routine which actually writes the flight data out to magnetic tape. To begin the data collection respond to the RTS/8 asterisk by typing

*ON,TAPE

The tape will then begin recording data. A record will be written every three (3) seconds.

6.2.2 Program LWCD

The LWCD program provides the capability of monitoring liquid water content in real time. Liquid water content is calculated, averaged, and displayed for a time interval defined by the operator. Five different particle types are supported and the cloud or precip probes may be used exclusively if desired.

To run LWCD respond to the RTS/8 system asterisk by typing

*ON,LWCD

LWCD will then print

VELOCITY (KNOTS)

respond by typing the velocity in knots (an integer) and return. Note that all inputs to LWCD are terminated by return.

LWCD then prints

SAMPLE PERIOD (SECS)

respond by typing the sampling period to use. This must be a multiple of 3. (3,6,9,12, etc.) During a run of LWCD the average liquid water content during each sampling interval is displayed on the Tektronix screen. After the sample period has been entered LWCD will print

PARTICLE TYPE

respond by typing the particle type number (an integer from 1 to 5). The particle types currently supported by LWCD are:

1 Rain
2 Small snow
3 Large snow
4 Wet snow
5 Bullet-Rosettes

LWCD then prints

PROBE

respond by typing C to use only the cloud probe
P to use only the precip probe
or just return to use both

LWCD is now running and will display liquid water content for every sample period.

After every sample period the following line of output is displayed on the screen.

```
HH:MM:SS TYPE X  LWC X.XX
```

where HH:MM:SS is the flight time clock

TYPE X is the particle type number being used in liquid water content calculation (input by operator)

LWC X.XX is the average liquid water content in grams per cubic meter over the sampling period input by the operator

To terminate a LWCD run respond to the system asterisk by typing

```
*OFF,LWCD
```

(To get the system asterisk strike any key while LWCD is running.)

6.3 REAL TIME SYSTEM RTX/8

In addition to the support and maintenance DPSI has provided on the initial system (RTS/8), we have designed and developed a completely new real time operating system RTX/8. As the year progressed, improvements that would enhance both the quality and quantity of the data collected became more apparent. After considerable discussion and planning the consensus of opinion was to create a new system rather than completely revise the original. Externally, to the user, both systems appear similar; however the level of sophistication utilized in the new software prcvides for far more versatility as future requirements change, as well as an improved data collection system.

The heart of the new RTX/8 system utilizes the concept of event processing. An event is a two-state condition (either true or false) that is used to keep track of a particular occurence while the system is running. (The reader should keep in mind that many of these occurences take place in a given instance.) The generality of this event scheme is extremely useful in a real time environment where many independent functions occur simultaneously. When these functions reach a significant point in their execution, the computer must recognize this fact and initiate whatever action is required. As an example of a significant point in the processing stream, consider the task of filling a data buffer. As the data is being collected by the system and stored in the buffer, a significant point occurs when the data buffer becomes full. At this time the "full data buffer" event flag is set to true. Setting this flag true signals another program to record the buffer on magnetic tape.

After the data buffer is recorded the event flag is cleared (i.e. set to false) and the process is repeated. The following list shows some of the on going functions that utilize this event flag technique.

1. PMS synch pulse detected
2. Tektronix screen erased
3. PMS buffer processing completed
4. Operator typed ↑C on keyboard
5. Liquid water content calculation completed
6. Magnetic tape error detected

The versatility of this technique is apparent from this list of functions. Tasks to the system may be added or deleted easily without affecting the overall processing flow. This event-flag scheme has another powerful advantage over the earlier system. In certain applications the status of one event is important to many different programs and specialty routines.

Consider the operation of the Tektronix screen. This device is used by many different programs (plus the operator) during data collection. When the screen becomes full it must be copied and erased; all programs using the screen must be made aware of that fact. The plotting program, for example, must redraw the axes and begin plotting at the origin. Only one event flag is required to inform all the other user programs that the screen has been erased.

The event-flag technique allows many functions to be performed, that would have been impossible otherwise. Some of these capabilities are listed below:

1. Simultaneous usage of both the Tektronix screen and GE printer as independent input/output devices

2. Detecting and reporting all errors due to magtape problems or data transmission

3. Reporting all inoperable devices

4. Monitor integrity - i.e. user programs cannot cause system crashes

5. Complete communication between all user programs if desired

Full exploitation of this concept offers numerous advantages that were unavailable to the earlier system. At this time RTX/8 is fully operational; additional features will be installed in the near future.

6.4 POST MISSION DATA REDUCTION SYSTEM

The post mission data reduction system consists of a series of programs which read 1D PMS tapes or PDP8 generated tapes and perform various lookup and display options. Specific time intervals may be retrieved. These programs would be used on site for preliminary data analysis prior to processing on the AFGL CDC 6600.

6.4.1 Proram QWIKY

QWIKY performs a quick look type dump for all 1D PMS and PDP8 data tapes. PMS tapes may be used from the C130A or the C130E. The dump printed by the program includes time printouts, raw and calibrated VCO's, total probe counts, and certain values derived from this data.

The program may be run in two different modes. The first mode dumps the entire tape printing averages over a specified interval. The second mode allows flight time or elapsed time to be used to locate a record. This feature will be useful in locating the start of a sampling run or any time interval of interest. The operating instructions for QWIKY are shown on the following four pages.

1. Mount the magtape to be dumped on unit 0 with the write enable ring removed to prevent any possible corruption of data

2. Turn on the GE Terminet printer, press the 'ON LINE' button and be sure that the paper is free to feed.

3. Respond to the OS/8 dot (.) by typing "R KNMON" (return). (for detailed explanation of how to get the OS/8 dot refer to section 6.1, Bootstrapping the Computer.

   When QWIKY is started it will print

   QUICK-LOOK PROGRAM
   FLIGHT TAPE (F) OR KENNEDY TAPE (K)?

4. Respond by typing F if the magtape is a PDP8 generated flight tape of K if the tape is from the Kennedy tape recorder in the PMS system. Terminate input with a return. Note: <u>all</u> inputs to QWIKY are terminated with return. If K is input the program will then print

   A or E?

5. Respond with A if the tape is from the C130A or E if the tape is from the C130E. The program will then print

   FLIGHT NO., DATE?

6. Enter the flight number and date or a string of up to 30 characters which identifies the tape. The program then asks

   ALL (A) OR SPECIFIED (S) TIMES?

7. Respond with A to dump the whole tape starting at whatever record the tape head is currently at. The program will not rewind the tape to the load point before dumping. This is useful if the program fails to locate a specified time interval. The operator may position the tape to approximately where the desired time whould be using the off line controls on the TU10. The A option may then be used to determine what was recorded on the tape. There is one small problem associated with this procedure. When the off-line controls

are used to forward space or backspace the tape the TU10 does not stop on an even record boundary. Therefore the first few seconds of data produced by the program should be ignored if tape has been moved with the off-line controls. The program will detect this error condition and print

!!!INCORRECT MAGTAPE RECORD LENGTH!!!

This printout is normal after the tape has been moved with the off-line controls, however it should only print once. The first read done by the TU10 will reposition the tape head to the beginning of a record and subsequent records should be readable without generating this error. If this printout repeats continuously the tape is not in the correct format and any results printed by the program will be incorrect.

8. The S option allows the operator to specify a time interval on the tape to be dumped. If this option is selected the program then prints

CLOCK (C) OR ELAPSED (E) TIME?

Type C to use the flight time clock to look up records or E to use the PMS buffer elapsed time. The program will attempt to find the specified time interval no matter where it is on the tape and will minimize tape motion as much as possible. If the tape has gone beyond the time interval desired the program will backspace as necessary. It is not necessary to rewind the tape to the load point before each run.

After the operator has specified which clock to use the program will print

START TIME

9. Respond by typing the starting time for the dump in the form SSSS to specify a four digit elapsed time in seconds or HH:MM:SS to specify a flight time. The program will then print

STOP TIME

10. Respond with the time to stop the dump at in the same form used for the starting time.

The program now asks

AVERAGING INTERVAL (SECS)

11. This question is printed for both the specified time interval and dump all times mode. Respond with the number of seconds to be represented in each printout.

The program then begins calculating averages over the specified time interval and printing a report for each interval. Contained in each printout are the start and stop flight and elapsed times for the interval, average VCO values, average values of parameters derived from the VCO's, and <u>total</u> probe counts.

12. The program may be restarted from the beginning by setting the switches to 0200 and pressing HALT, ADDR LOAD, EXT ADDR LOAD, CLEAR, CONTINUE.

13. Alternatively the program can be restarted from the "ALL (A) OR SPECIFIED (S) TIMES?" question by setting the switches to 0000 and pressing HALT, ADDR LOAD, EXT ADDR LOAD, CLEAR, CONTINUE.

Error Recovery Procedures

The following error messages may print out during execution of QWIKY.

printout	possible cause(s)	recommended action(s)
TIME INTERVAL OUT OF RANGE	time specified not on tape	use "A" option to see what is on tape
END OF TAPE	time specified not on tape	rewind tape and try another time interval
!!!MAGTAPE PARITY ERROR!!!	bad tape, bad TU10	try another tape;if the printout is infrequent it may be ignored;however if data looks bad this is the cause
!!!INCORRECT MAGTAPE RECORD LENGTH!!!	bad tape (unlikely) question asking if tape was Kennedy tape (PMS) or Flight tape (PDP8) was answered incorrectly tape head was not on even record boundary due to operator moving it using off-line controls	try another tape;restart program at 0200 and answer question correctly no action necessary simply ignore results of first averaging interval

Some errors will not be detected by the program. Following is a list of the conditions and recommended actions.

disposition	possible causes(s)	recommended action(s)
TU10 "rocks" and will not locate time specifies	bad times on tape	use "A" option to dump tape
program will not load	bad system tape unknown	try backup system tape notify DPSI
program "hangs up"	unknown	record AC, PC, MQ and notify DPSI
program halts	unknown	record AC, PC, MQ and notify DPSI

6.4.2 Program IBOL

IBOL provides the means of retrieving flight data from flight data tape created by the RTS/8 real time data collection program. Data from the Knollenberg probes is specified by VCO number and may be retrieved on the basis of time, referencing either the aircraft clock or the elapsed time counter of the Knollenberg device. Data may be printed on the line printer or displayed on the CRT (DECwriter for Lab version) as specified by the operator.

To run IBOL mount the PDP8 generated flight tape with the write enable ring removed to prevent any possible corruption of data

Turn on the GE Terminet printer, press the 'ON LINE' button and be sure that the paper is free to feed.

Respond to the OS/8 dot (.) by typing "R IBOL" (return).

Once initiated by the R IBOL directive the IBOL program requests input from the operator regarding the flight identification, reference clock, start and stop times for the data desired and finally a list of the Knollenberg words to be retrieved and displayed.

Once the required parameters have been supplied, the program IBOL will commence a search of the records of the RTS/8 flight tape until the data of the specified time period is located. The desired KNW values will then be retrieved and displayed on either the CRT or line printer depending upon which has been specified as the output device as follows:

Set switch register bit zero:

SR bit 0 = 0 output on CRT (DECwriter for lab version)

SR bit 0 = 1 output on Line Printer

When all the data for a given time interval has been displayed, the program will initiate itself to allow a new pass. The data tape is not rewound at this time. (see example of program operation)

operator inputs (all underlined characters are program generated)

A) FLIGHT IDENTIFICATION
NOTE: MAKE OUTPUT DEVICE SELECTION NOW

operator may enter up to 500 characters to provide an identification text which will appear on the output (if the line printer is selected as the output peripheral, or on the CRT if it is the specified output device.) Any character may be entered with the exception of the back slash which is used to terminate entry.

NOTE: Errors during entry of the flight id can be corrected by use of the 'rubout' key. Each time the rubout key is depressed, the last character is erased from the identification string. To restart the entire id entry operation, simply depress 'control' and 'C' simultaneously.

B) ENTER AC OR ET FOR CLOCK SELECTION

operator responds by typing AC (space) if the aircraft clock is to be used as the time reference for data interval specification ET (space) if the elapsed time from Knollenberg is to be used as the time reference.

C) BEGIN ...

enter start time of the interval over which data is to

be retrieved. Two formats are used depending upon the clock selection made in step (B).

1) if AC was selected, the program expects a time given in the form of hours, minutes and seconds:
   HH:MM:SS (space)

2) if ET was selected, the program wants an elapsed time in seconds between 0 and 9999:
   1234 (space)

D) <u>END .....</u>

enter the finish time of the interval over which data is to be retrieved. The form of time entry must be the same as step (C).

E) <u>*ENTER KNW SELECTION FOR DISPLAY*</u>
<u>TERMINATE OPERATION WITH A SPACE</u>

operator may enter the KNW numbers to be retrieved and displayed. The range of KNW numbers is 1 to 63. Selection of KNW numbers outside that range will result in incorrect values.

KNW numbers may be specified as individual numbers separated by commas or as a sequence of contiguous KNW's by means of a dash to separate the first from the last KNW. In each case, the KNW number or sequence must be followed by a comma with the exception of the last number which is followed by a slash to terminate the operation.

example: To display KNW numbers 1,6 thru 12,9,22 and 45 thru 63, the following type in is made:

1,6-12,9,22,45-63 (/)

NOTE:
Errors made during the entry of KNW numbers may be corrected by depressing the 'rubout' key. This has the effect of clearing any partially input number and allowing a new entry. Once the number has been completed however, (terminated with a comma, space etc.) the rubout will have no effect. Note also that operation of the rubout key will not result in carriage motion or character echo.

Once the required information has been provided to the program, the desired data is located on the RTS/8 flight tape and transmitted to the device selected as the output peripheral (CRT or line printer).

Data is recovered until the end of the interval specified in step D is reached. At such time, the message 'END DATA' is typed and the program automatically reinitiates itself for another run. If for some reason, the run must be interrupted and new parameters used, striking any key will cause the program to re-initialize itself after the current display operation.

On completion of any given run, the flight data tape is positioned at the point of last data acquisition. If it is necessary to recover other KNW values from an earlier time period on the same flight tape, the tape must be manually rewound prior to commencing the run.

6.5 TESTING and CALIBRATION

Shortly before a scheduled data collection mission, it is desirous, whenever possible, to perform certain system tests. This insures that the data collected will be of the best quality prossible. Many minor system malfunctions can be corrected at this time. Also, periodically throughout the season, the VCO calibrations are rechecked. The program KNMON was written to assist the flight crew when performing these tests.

6.5.1 Program KNMON

This program was developed for testing and checking out of the PMS interface and associated M1703 card in the computer. Any desired Knollenberg channel may be selected for monitoring by the operator. The channel selected is printed every second since the PMS system sends its blocks of information at this rate. Since the channel is printed every time the PMS system sends it to the computer, printout from the program should be useful for calibration work and troubleshooting VCO's in addition to checkout of the basic PMS buffer functions and the sync word.

To operate the program

1. Respond to the OS/8 dot by typing "R KNMON" (return).

2. After KNMON is started it will print

   KN CHANNEL

   Respond by typing the Knollenberg channel to monitor (from 1 to 64) followed by return. The program will then print the value of the selected channel every second.

3. To select another channel set SR to 0200 and press 'HALT', 'LOAD ADDRESS', 'EXTD ADDR LOAD', 'CLEAR', 'CONTINUE' then continue from step 2.

7. ADDITIONAL TASKS

During the year certain tasks became apparent that would ease the everyday processing, and in some cases the analysis, that occurs at LYC. Usually these take the form of short real-time programs to be used on the CDC 6600 terminal; however, in some cases the DEC PDP8/I and E are utilized. In all cases the goal is to eliminate some of the tedious but necessary work required of the LYC scientists.

7.1 Program LOOP

Program LOOP is the last analysis performed in the post flight processing. As a result of the runs of KNOLL1D and RAPP, the relationships between radar reflectivity and liquid water content are calculated by fitting functions. A missile will be fired into this same cloud formation after the aircraft has landed, and radar observations will be taken as the missile passes through the atmosphere. The radar response will be values of reflectivity for which liquid water content will be desired. (These z values are taken from the LYC "storm top" plot.)

The input to program LOOP is handled by a special program called BOBIN. Both LOOP and BOBIN are designed to be executed at the 6600 terminal, with output printing at the computer center.

BOBIN will first request the 21 points which describe number density versus size. These 21 numbers are output from KNPLT1D. The diameters of these 21 points are fixed at .075, .15, .25, and from .4 to 3.8 spaced at .2. The program will also request the three sets of A, B coefficients from KNPLT1D and RAPP. These three A's and B's are described below:

$$M_a = A_1 Z_a^{B_1} \qquad \text{from RAPP}$$

$$K = A_2 Z_r^{B_2} \qquad \text{from RAPP}$$

$$D_0 = A_3 (Z_a/M_a)^{B_3/3} \qquad \text{from KNPLT1D}$$

where the subscript 'a' indicates an aircraft derived parameter and the subscript 'r' indicates a radar derived parameter

Program BOBIN allows the user to print and modify any of these 27 values (21 points from KNPLT1D, 2 sets of A, B from RAPP and A_3, B_3. When satisfied, control is tranferred to program LOOP for execution. This separation of function was done in order to allow LOOP a restart function without having to reinput the 27 numbers. It is especially useful for rerun, and in the event System I at the computer center crashes. Program BOBIN creates a permanent disk file of these numbers; it also purges the previous file when a new file is made and updates the cycle number. This data file is called X4340.

Program LOOP will determine the mass (M) and median volume diameter (D_0) for measured radar reflectivity using empirical distributions of dimensionless diameter (D/D_0) vs. dimensionless number density ($ND_0{}^4/M$). A short scientific paper has been written describing the techniques for this determination. This paper in its entirety is included here.

From the running of analysis programs on flight data (see KNOLL1D and RAPP in "DEVELOPMENT AND APPLICATION OF DATA PROCESSING TECHNIQUES AND ANALYTIC PROCEDURES TO CLOUD PHYSICS DATA", by Belsky, Kaplan and Rodenhiser, AFCRL-TR-75-0427, 28 July 1975) three fitting functions are produced. The first yields a fit of 22 points of D/D_0 (equivalent melted diameter over median volume diameter) by $ND_0{}^4/M$ (number times the fourth power of median volume diameter divided by the liquid water content). The second produces a least square fit of the parameter (mk) such that

$$(mk) = A_1 \; Z^{B_1}$$

where (mk) is defined as the liquid water content divided by the square root of the radar reflectivity, Z is the radar reflectivity and A_1 and B_1 are the fitting parameters. The third produces a least square fit to the median volume diameter such that

$$D_0 = A_2 \; (M/Z)^{B_2/3}$$

where M is, again, the liquid water content and the A_2 and B_2 are fitting parameters.

Our task is for a given $(D/D_0)_{max}$, and a given radar reflectivity, Z_R, to find the D_0 and M which satisfy the equations

$$Z_R = \int_0^\infty D^6 \frac{M}{D_0{}^4} F dD$$

$$M = \frac{\pi}{6} \int_0^{\infty} D^6 \frac{M}{D_0{}^4} FdD$$

$$Z_{OBJ} = \int_0^{(D/D_0)_{max}} D^6 \frac{M}{D_0{}^4} FdD$$

$$M_{OBJ} = \frac{\pi}{6} \int_0^{(D/D_0)_{max}} D^3 \frac{M}{D_0{}^4} FdD$$

$$M_{OBJ} = (mk)\sqrt{Z_{OBJ}}$$

where F is the output function $ND_0{}^4/M$
M is the mass, or liquid water content
D_0 is the median volume diameter
Z_R is a measured radar reflectivity
D is an integration variable
$(D/D_0)_{max}$ is the instrument maximum (will be referred to as IM)

The reported output for F, or $ND_0{}^4/M$ is actually their logs base 10. It will thus be more convenient to write 10^y for F, where y's are the numbers actually being printed. In addition, the third fitting function:

$$D_0 = A_2 \, M^{B_2/3}$$

will be used solely to obtain an original estimate to D_0.

The analysis for solution follows.

given the following equations

$$1 \qquad \hat{M} = \frac{\pi}{6} \int_0^\infty D^3 \frac{M}{{D_0}^4} 10^Y \, dD$$

$$2 \qquad \frac{\hat{M}}{2} = \frac{\pi}{6} \int_0^{D_0} D^3 \frac{M}{{D_0}^4} 10^Y \, dD$$

$$3 \qquad \frac{\hat{M}}{2} = \frac{\pi}{6} \int_{D_0}^\infty D^3 \frac{M}{{D_0}^4} 10^Y \, dD$$

$$4 \qquad Z = \int_0^\infty D^6 \frac{M}{{D_0}^4} 10^Y \, dD$$

$$5 \qquad M_{OBJ} = (mk)\sqrt{Z_{OBJ}}$$

$$6 \qquad M_{OBJ} = \frac{\pi}{6} \int_0^{IM} D^3 \frac{M}{{D_0}^4} 10^Y \, dD$$

$$7 \qquad Z_{OBJ} = \int_0^{IM} D^6 \frac{M}{{D_0}^4} 10^Y \, dD$$

investigating the first three equations, it is helpful to replace 10^Y with

$$N_0 \, e^{-kD/D_0}$$

(see "Snow Size Spectra and Radar Reflectivity" by Sekhon & Srivastava Journal of American Sciences, Vol 27, No 2 March 1970 pp 299-307)

then

1A $$\hat{M} = \frac{M}{D_0{}^4}\,\frac{\pi}{6}\,N_0 \int_0^\infty D^3 e^{-kD/D_0}\,dD$$

2A $$\frac{\hat{M}}{2} = \frac{M}{D_0{}^4}\,\frac{\pi}{6}\,N_0 \int_0^{D_0} D^3 e^{-kD/D_0}\,dD$$

3A $$\frac{\hat{M}}{2} = \frac{M}{D_0{}^4}\,\frac{\pi}{6}\,N_0 \int_{D_0}^\infty D^3 e^{-kD/D_0}\,dD$$

dividing 2A by 3A yields

4A $$1 = \frac{\int_0^{D_0} D^3 e^{-kD/D_0}\,dD}{\int_{D_0}^\infty D^3 e^{-kD/D_0}\,dD}$$

this can be integrated directly, yielding

$$1 = \frac{\frac{6D_0{}^4}{k^4} - \left(\frac{D_0{}^4}{k} + \frac{3D_0{}^4}{k^2} + \frac{6D_0{}^4}{k^3} + \frac{6D_0{}^4}{k^4}\right)e^{-k}}{\left(\frac{D_0{}^4}{k} + \frac{3D_0{}^4}{k^2} + \frac{6D_0{}^4}{k^3} + \frac{6D_0{}^4}{k^4}\right)e^{-k}}$$

this can be simplified to

$$3e^{k} - (k^3 + 3k^2 + 6k + 6) = 0$$

and solved for k. In this case $k \doteq 3.67206075$

The more important result is that maintaining equation 4A is independent of D_0. That is, provided D_0 is chosen finite and greater than zero, this relationship must be maintained. This suggests that our function be changed from

10^{Y} to $10^{\alpha Y}$, where α is chosen such that the following equation holds

$$1 = \frac{\int_0^{D_0} D^3 \, 10^{\alpha Y} \, dD}{\int_{D_0}^{\infty} D^3 \, 10^{\alpha Y} \, dD} \qquad \text{assume } D_0 = 1$$

Furthermore from equation 1

$$\hat{M} = M \left[\frac{\pi}{6} \int_0^{\infty} D^3 \frac{10^{\alpha Y}}{{D_0}^4} \, dD \right]$$

This equation is also independent of the choice of D_0. This remarkable fact can be seen from adding equations 2A and 3A, yielding

$$\hat{M} = N_0 \frac{M}{{D_0}^4} \frac{\pi}{6} \left(\frac{6{D_0}^4}{k^4}\right)$$

or $$\hat{M} = M \left[\frac{\pi}{k^4} \right] N_0$$

which is independent of D_0.

In order to make $\hat{M}$ approach M, however,

$$\frac{\pi}{6} \int_0^\infty D^3 \frac{10^{\alpha Y}}{D_0{}^4} dD \qquad \text{must equal 1.}$$

If not identically 1, no value of $\hat{M}$ will be found, and if equal to 1, any value of $\hat{M}$ will satisfy.

Since this integral will not equal 1 in a general case we introduce β, such that

$$\beta = \frac{6}{\pi} / \int_0^\infty D^3 \frac{10^{\alpha Y}}{D_0{}^4} dD$$

again choosing $D_0 = 1$.

From equations 1 to 7 we have

1B $$\hat{M} = \frac{\pi}{6} \frac{M\beta}{D_0{}^4} \int_0^\infty D^3 \, 10^{\alpha Y} \, dD$$

2B α is the solution of

$$\int_0^1 D^3 10^{\alpha Y} \, dD = \int_1^\infty D^3 \, 10^{\alpha Y} \, dD$$

3B $$\beta = \frac{6}{\pi \int_0^\infty D^3\ 10^{\alpha Y}\ dD}$$

4B $$Z = \frac{M\beta}{D_0{}^4} \int_0^\infty D^6\ 10^{\alpha Y}\ dD$$

5 $$M_{OBJ} = (mk)\sqrt{Z_{OBJ}}$$

6B $$M_{OBJ} = \frac{\pi}{6}\frac{M\beta}{D_0{}^4} \int_0^{IM} D^3\ 10^{\alpha Y}\ dD$$

7B $$Z_{OBJ} = \frac{M\beta}{D_0{}^4} \int_0^{IM} D^6\ 10^{\alpha Y}\ dD$$

combining equations 5, 6B, 7B

$$\frac{\pi}{6}\frac{M\beta}{D_0{}^4} \int_0^{IM} D^3\ 10^{\alpha Y}\ dD = (mk)\sqrt{\frac{M\beta}{D_0{}^4} \int_0^{IM} D^6\ 10^{\alpha Y}\ dD}$$

squaring both sides:

$$\left(\frac{\pi M\beta}{6D_0{}^4}\right)^2 \left\{\int_0^{IM} D^3\ 10^{\alpha Y}\ dD\right\}^2 = (mk)^2\ \frac{M\beta}{D_0{}^4} \int_0^{IM} D^6\ 10^{\alpha Y}\ dD$$

and solving for M

$$M = \frac{(mk)^2\ \dfrac{\beta}{D_0{}^4} \displaystyle\int_0^{IM} D^6\ 10^{\alpha Y}\ dD}{\left(\dfrac{\pi\beta}{6D_0{}^4}\right)^2 \left\{\displaystyle\int_0^{IM} D^3\ 10^{\alpha Y}\ dD\right\}^2}$$

or

$$M = \frac{(mk)^2 \displaystyle\int_0^{IM} D^6\ 10^{\alpha Y}\ dD}{\dfrac{\beta}{D_0{}^4}\ \dfrac{\pi^2}{36}\left\{\displaystyle\int_0^{IM} D^3\ 10^{\alpha Y}\ dD\right\}^2}$$

combining this result with equation 4B, we have to solve for D_0 such that

$$Z_R = \left(\frac{M}{D_0{}^4}\right)\ \beta \int_0^{\infty} D^6\ 10^{\alpha Y}\ dD$$

where

$$\left(\frac{M}{D_0{}^4}\right) = \frac{(mk)^2 \displaystyle\int_0^{IM} D^6\ 10^{\alpha Y}\ dD}{\dfrac{\beta\pi^2}{36}\left\{\displaystyle\int_0^{IM} D^3\ 10^{\alpha Y}\ dD\right\}^2}$$

The system yields

α, β which are independent of Z_R, and depend only upon the given distribution $Y(D/D_0)$

D_0 the solution of the preceding equation

M an auxiliary value in the preceding equation

Z_{OBJ} as defined by 7B

M_{OBJ} as defined by 5

1. by Newton's method, find α such that

$$\int_0^1 D^3\, 10^{\alpha Y}\, dD = \int_1^\infty D^3\, 10^{\alpha Y}\, dD$$

by forming

$$F(\alpha) = \int_0^1 D^3\, 10^{\alpha Y}\, dD - \int_1^\infty D^3\, 10^{\alpha Y}\, dD$$

then letting $\alpha = \alpha_0$, a starting value (generally 1)

form $F(\alpha_k)$, $F(1.01\alpha_k)$

then $F' = 100[F(1.01\alpha_k) - F(\alpha_k)]/\alpha_k$

and $\alpha_{k+1} = \alpha_k - F(\alpha_k)/F'$

the process is continued until $\alpha_{k+1} - \alpha_k \to 0$

2. Find β

$$\beta = \frac{6}{\pi \int_0^\infty D^3\, 10^{\,Y}\, dD}$$

3. By Newton's method, find D_0 such that

$$Z_R = \gamma\beta \int_0^{\infty} D^6\, 10^{\alpha Y}\, dD$$

where

$$\gamma = \frac{36(mk)^2 \int_0^{IM} D^6\, 10^{\alpha Y}\, dD}{\beta\pi^2\left[\int_0^{IM} D^3\, 10^{\alpha Y}\, dD\right]^2}$$

by forming

$$G(D_0) = \gamma\beta \int_0^{\infty} D^6\, 10^{\alpha Y}\, dD - Z_R$$

then letting $(D_0)_0 = A_2\, M^{\beta_2/3}$ as a starting value

form $\quad G((D_0)_k), G(1.01(D_0)_k)$

then $\quad G' = 100[G(1.01(D_0)_k) - G((D_0)_k)]/(D_0)_k$

and $\quad (D_0)_{k+1} = (D_0)_k - G((D_0)_k)/G'$

the process is continued until $(D_0)_{k+1} - (D_0)_k \to 0$

4. Find M

$$M = \frac{36\, D_0^{\,4}\, (mk)^2 \int_0^{IM} D^6\, 10^{\alpha Y}\, dD}{\beta\pi^2\left[\int_0^{IM} D^3\, 10^{\alpha Y}\, dD\right]^2}$$

The operating instructions for these two programs are found on the following pages.

To enter, alter, print data file (BOBIN)

```
COMMAND-ATTACH,DATA,BOBINX4340,ID=BELSKY↓
[if LFN ALREADY IN USE, or          ]
[   PF ATTACHED go to next step     ]

COMMAND-REQUEST,NFILE,*PF↓
 if get duplicate message: COMMAND-UNLOAD,NFILE,FILE↓
                           COMMAND-REQUEST,NFILE,*PF↓

COMMAND-DATA
[if program doesn't run: COMMAND-UNLOAD,DATA↓]
[           go to top line                   ]
```

To execute calculating program (LOOP)

```
COMMAND-ATTACH,LGO,LOOPX4340,ID=BELSKY↓
[if LFN ALREADY IN USE, or          ]
[   PF ATTACHED go to next step     ]

COMMAND-LGO
[if CANNOT ATTACH DATA FILE: COMMAND-UNLOAD,NFILE,FILE]
[                            COMMAND-LGO              ]
```

To end run, type Z_r=0. (ALWAYS TYPE DEC. PT. IN RESPONSE TO ZR,INSTR.MAX,MK)

To get rid of output: COMMAND-DISPOSE,TAPE6↓

<u>After</u> <u>running</u> <u>LOOP</u>: COMMAND-UNLOAD,NFILE,FILE↓

To Rerun BOBIN: COMMAND-REQUEST,NFILE,*PF↓
COMMAND-DATA↓

To Rerun LOOP: COMMAND-LGO↓

Errors during typing

to erase a character type CTRL/H; one character is erased for each time the keys are depressed.

to erase an entire line, type CTRL/X; then type as if nothing had been previously typed.

LOGIN:	LOGIN,LOREN,LYB449,SUP↓
	LOGIN,MORT,LIA178,SUP↓
	LOGIN,FRED,LZ0461,SUP↓

trouble X4546 (operator) X4005 (D. Caveliero)

IF, in BOBIN, the message

CANNOT CATALOG DATA FILE. ERROR NO. 015

all is not lost! simply type

```
COMMAND-CATALOG,NFILE,X4340,ID=BELSKY,CY=1↓
COMMAND-PURGE,FILE↓
COMMAND-UNLOAD,FILE↓
```

7.2 Program RAIN

RAIN is the program for processing the raindrop spectrometer data. This data is recorded in analog form from the raindrop spectrometer directly. The analog tape is run on the LYC PDP8I computer via the analog to digital converter, and the digitized results are written on the magnetic tape and printed on the high speed printer.

The output from the PDP8I is run by program RAIN on the CDC 6600 in order to produce the desired results. The format for the records on the magnetic tape will be found in appendix 38. These records are preceded by a "header" record of 52 alphabetic characters, and they are followed by an end-of-file. The 26 channels contain counts of raindrops for 1 second, by diameter class.

The diameter class depends upon the number of bits (k) used in the analog to digital conversion. This value of k will have to be furnished to program RAIN, and is given by the A to D operator. The operator is working with voltage values on the analog tape. He will determine k in such a way that the voltage values will be divided into the 26 classes without obtaining values beyond this range. At the same time, if k is too large, all values will be in the beginning of the 26 classes without sufficient separation. That is, too large a k yields too small a resolution.

The program, itself, will calibrate these results, calculate liquid water content (M), reflectivity (Z) and rain rate (R). It will also plot

M vs. Z

R vs. Z

M vs. R

time vs. M

time vs. R

time vs. Z

Finally the last plot will show, for each P second period, number density (N) vs. diameter, with a Marshall-Palmer line fit through the spectrum.

To determine the diameters for each of the 26 channels:

$$d_m = \sqrt{(22.5)\ \frac{2.5}{2^k} m + 4.3} \qquad \text{(microns)}$$

where

m = channel number

k = number of bits in A to D conversion

and we define $d_0 = \sqrt{4.3}$

The midpoint diameter value (D_m) for any one of the 26 classes is given by

$$D_m = \frac{d_{m-1} + d_m}{2} \qquad \text{(microns)}$$

It is interesting to note, as an aside, that the maximum diameter is a function of k, the number of bits in the A to D conversion. The minimum diameter is always 2.0736 microns (d_o), and the maxima for some selected k values are:

bits(k)	maximum diameter (microns)
5	7.0713
6	5.2107
7	3.9656
8	3.1643

The formulas used in the calculation are:

Number density, N_m

$$N_m = \frac{count_m}{v} \qquad (counts/m^3)$$

where v is sampling volume

Liquid water content, or mass, M_m

$$M_m = \frac{\pi}{6} N_m \rho D_m^3 \qquad (gms/m^3)$$

where ρ = water density

Radar reflectivity, Z_m

$$Z_m = N_m D_m^6 \qquad (mm^6/m^3)$$

Rain rate, R_m

$$R_m = \frac{(3600)(14.2)}{1000} \sqrt{\frac{D_m}{10}} \qquad (mm/hr)$$

and these are summed over the 26 classes to produce results for the 1 second interval:

$$M = \sum_m M_m$$

$$Z = \sum_m Z_m$$

$$R = \sum_m R_m$$

There are two peculiarities of the magnetic tape that cause difficulty. The first is that channel 1 gives spurious results and the data for the first channel must be ignored. Secondly, the time on the tape, (hours, minutes and seconds) is often incorrect. This second fault requires that time will have to be controlled externally.

Since the time cannot be relied upon, the user will supply the time of the first data record, and each subsequent record will have a time of one second later, until an end-of-file is seen. Thus, there will have to be a beginning-time given for each file. These times can be determined from the high speed printout of the PDP8I during the writing of the magnetic tape.

7.3 Program HELP

HELP is a program designed to run in a conversational mode on the 6600 time sharing system INTERCOM. The program will produce a punched deck or disk file containing all the input required to run the programs KNOLL1D or KNPLT1D. The output consists of: a job card, control cards, and data cards. It is particularly useful when many decks have to be generated. A disk file is produced that allows the job to be submitted through the BATCH remote entry system. Operation of this program is quite simple; the sample run on the following pages contain all the information necessary for execution.

```
COMMAND- ATTACH HELP,HELPBINX2876,ID=GLASS

COMMAND- CONNECT,INPUT

COMMAND- CONNECT,OUTPUT

COMMAND- HELP

ENTER DESIRED PROGRAM NAME...KNOLL1D


JOB NAME(5 CHAR)?GLAA8

(B)INARY OR (S)OURCE?  B

CYCLE,I3 OR BLANK FOR LATEST..209

PROGRAM NAME..KNOLL1D

INPUT TAPE NO. ?  LYC136

PLOT TAPE NO.?  LYC178

RAPP TAPE NO.?  LYC179

CHANGING DCOEF?  N

CHANGING PCOEX?  N

CHANGING SCOEF?  N

(A) OR (E) FLIGHT?  A

DO YOU WISH TO SEE THE VCOEF.?  N

CHANGING VCOEF?  N

START TIME- ENTER AS HHMMSS..210900

STOP TIME- ENTER AS HHMMSS..221300

FLIGHT ID ENTER AS XYR-NN..A76-14

FLIGHT DATE- ENTER AS DD MON YR..25 APR 76

PMS ONTIME AS HHMMSS..210157

TYPING BY (M)ANUAL INPUT OR (T)EMP..M

(A)/C CLOCK OR (P)MS BUFFER..A

(P)RELIM OR (F)INAL DATA..F

WHAT AVE INTERVAL (IN SECONDS(I2))..04
```

```
TEMP BY (V)CO, (A)TMOSPHERE, OR (R)ADIOSONDE..V

CALCULATE VCO? YES

SKIP HOW MANY FILES (I2)..00

PUNCH DECK?  NO

(K)WAJ OR (S)TANDARD?  S

DATA MODIFICATION?NO

(T)YPE OR (E)DIT OR (N)EITHER..T

START TIME- ENTER AS HHMMSS..211000

STOP TIME- ENTER AS HHMMSS..211500

FOR CLOUD CODE..07

FOR PRECIP CODE..07

(T)YPE OR (E)DIT OR (N)EITHER..T

START TIME- ENTER AS HHMMSS..211600

STOP TIME- ENTER AS HHMMSS..211800

FOR CLOUD CODE..07

FOR PRECIP CODE..07

(T)YPE OR (E)DIT OR (N)EITHER..T

START TIME- ENTER AS HHMMSS..212200

STOP TIME- ENTER AS HHMMSS..212900

FOR CLOUD CODE..07

FOR PRECIP CODE..07

(T)YPE OR (E)DIT OR (N)EITHER..T

START TIME- ENTER AS HHMMSS..215800

STOP TIME- ENTER AS HHMMSS..220200

FOR CLOUD CODE..05

FOR PRECIP CODE..05

(T)YPE OR (E)DIT OR (N)EITHER..N

     STOP
```

```
COMMAND- ATTACH HELP,HELPBINX2876,ID=GLASS

COMMAND- CONNECT,INPUT

COMMAND- CONNECT,OUTPUT

COMMAND- HELP

ENTER DESIRED PROGRAM NAME...KNPLTID

JOB NAME(5 CHAR)..GLAP9

CYCLE(I3), OR BLANK FOR LATEST...

INPUT TAPE...LYC178

 (B)INARY OR (S)OURCE...B

(L)EARJET OR (C)130...C

(P)EN OR (C)RT..C

(A)/C OR (P)MS CLOCK...A

(A)LL DATA OR JUST (S)UMMARY...S

FLIGHT ID ENTER AS XYR-NN...A76-14

FLIGHT DATE AS DD MON YR..25 APR 76

(R)EGULAR SET OR (D)EFINE WHICH ONES TO PLOT..R

THIS LOOP WILL ASK FOR EACH PASS INFORMATION WHEN LAST PASS IS GIVEN TYPE
  -1 FOR PASS NO.
THEN THE HEIGHT PROFILES WILL BE GENERATED FROM THE PREVIOUS INFORMATION
PASS NO.(I2)...01

START PASS TIME AS HHMMSS..211600

STOP PASS TIME AS HHMMSS..211800

HEIGHT(KILO) TIMES TEN (T.D=TD) IN (I3)..089

PASS NO.(I2)...02

START PASS TIME AS HHMMSS..212200

STOP PASS TIME AS HHMMSS..212900

HEIGHT(KILO) TIMES TEN (T.D=TD) IN (I3)..076

PASS NO.(I2)...21

START PASS TIME AS HHMMSS..215800

STOP PASS TIME AS HHMMSS..220200

HEIGHT(KILO) TIMES TEN (T.D=TD) IN (I3)..352

PASS NO.(I2)...-1
```

7.4 Program PLOT

Program PLOT was written for problems arising at LYC, where the data was not recorded on magnetic tape. Also, LYC had requirements for a plotting program which were dissimilar to the requirements for the on board computer.

Program PLOT will

(a) plot an x-y table on the Tektronix plotter; the table is inputted at the Decwriter. If desired, the x and/or y values can be modified by logging them in order to produce a linear-linear, a linear-log, a log-linear or a log-log plot.

(b) generate the x values automatically after a specification of the first x and x-step is given

(c) allow the user to select the low and high values of x and y to be used on the plot

(d) plot each point with +; the user can choose whether or not to connect the plotted points with a line

(e) label the plot with an alphabetic description

(f) plot a least square best fit curve to the data (first or second degree), and print out the fitting function

(g) generate a table of deviations of the least square fit to the original data, and calculate the RMS error

(h) allow the user to modify the data, limits and descriptions and replot, with a new least square fit, without having to retype the entire x-y table.

In order to execute program PLOT, and perform the many optional capabilities, the following step-by-step procedure should be executed:

1. Mount Dectape 136 on unit 0, write enabled and remote
2. Switches set to 7470
3. Press Addr-load, Ext.-addr-load, Clear, Cont
4. Computer responds with a dot
5. Type R PLOT
6. Within 22 seconds the computer responds with
   PLOTTING PROGRAM
7. IS X ON LOG SCALE?
   If the x-data is to be logged base 10, answer Y otherwise N
8. IS Y ON LOG SCALE?
   If the y-data is to be logged base 10, answer Y otherwise N
9. IS DELTA X CONSTANT?
   If the x-data (before taking logs) is equally spaced, answer Y, otherwise N
10. If delta x is constant, the computer will request X-START and DELTA-X, as X-START?
    Type the starting value and return,
    DELTA-X?
    Type the difference between successive x-values and return
11. The computer responds with
    ENTER X,Y TABLE
    or ENTER Y TABLE (for constant delta-x)

12. For each value input the computer will first print the index number (1,2,3,...etc) If only y-values are being inputted, the user will type the y-value followed by a return; if both x and y values are being inputted, the user will type the x-value, followed by a comma, followed by the y-value and a return.
13. When all values have been inputted, type

    1E35 return

14. The computer will respond with

    LIMITS OF X ARE xxxxx, xxxxx

    which indicate the low and high values of the x-table. Then it prints

    TYPE LIMITS TO USE

    The computer expects two numbers, separated by a comma, the first number is the value of x at the left end of the plot; the second is the value of x at the right end of the plot. There will automatically be 10 divisions in this range. If the first limit typed is unacceptable (larger than the limit found) or if the second limit typed (smaller than the limit found) is unacceptable, step 14 is repeated.
15. Step 14 is done for Y
16. The computer will print

    CONNECTING LINE?

    If a line is desired between points in the order they were typed in, answer Y. An answer of N will eliminate the connecting line.
17. The computer will respond

    TURN ON PLOTTER, TYPE DESCRIPTION

    Type a description to be printed on the bottom of the

plot. This description is limited to 67 characters. A rubout will respond with a carriage return, and the user should type the entire description over again.

Make sure plotter is on, and "on-line" before pressing return.

18. The plot will be made. At its conclusion, the computer will ask

    LEAST SQUARE FIT?

    If a curve fitting the data is desired answer Y; otherwise answer N and proceed to step 22.

19. The computer responds

    DEGREE(1 OR 2)?

    Degree 1 is a straight line fit; degree 2 is a quadratic fit. Respond either 1 or 2. Any other response will force step 19 again.

20. The fitting curve will be plotted. The least square polynomial will be printed

    (a) at the top of the plot, and

    (b) on the Decwriter

21. The computer then asks

    DEVIATIONS?

    If the table of x, y, calculated-y, deviation-y and RMS is desired, answer Y; otherwise answer N

22. The computer will ask

    REPLOT?

    If the data is to be modified, eliminated, or extended, or if another plot is to be made changing either x or y limits, or the description, or the fitting function, respond with Y; otherwise respond N and proceed at step 6

23. The computer will ask

NUMBER?

If there are no changes go to step 23(c).

(a) The computer expects the index number of the data point being changed. It will accept an index number one greater than the length of the table (omit the number corresponding to 1E35) with the assumption that the table is being extended. The table may be extended repeatedly by entering an index number equal to one more than the previous maximum number. If the number typed is invalid, step 23 is repeated. After the number is accepted, the computer will type X,Y =

Respond with the value of x, a comma, the value of y and return. Step 23 will be repeated. The data being typed will be logged according to responses made in steps 7,8

CAUTION: DO NOT ENTER 1E35 FOR THE LAST NUMBER. The program knows how many points there are in the table.

(b) If a value of x,y is to be eliminated, after its index number has been accepted, and X,Y = has printed, type

1E35,1E35 return

(c) When all changes have been made, answer NUMBER? with

0 return

The procedure restarts at step 14

ERRORS

1. Alphabetic errors: If an error is discovered before return is pressed, and the information was alphabetic, as in steps 7,8,9,16,17,18,19,21,22, type the rubout key; the computer will respond with a carriage return; retype the entire response, beginning with the first character.

2. Numeric errors: If an error is discovered before a comma or return is pressed, and the information was a number, as in steps 10,12,14 and 23, type the rubout key; the computer will not respond (automatic feature of the 27 bit floating point package); then type the entire number over again, beginning with the first character. CAUTION: If two numbers were being inputted, separated by a comma, the rubout will erase the CURRENT NUMBER ONLY.

3. Incorrect responses to Y or N: The computer will specifically look for the Y. Any character other than Y will be treated as N except a carriage return, which should be used only after a character has been typed.

RESTART ADDRESS: 0200

8. Operating Instructions

The deck setups for the various programs follow in sections 8.1 through 8.7:

8.1 KNOLL1D
8.2 KNPLT1D
8.3 KN1UTIL
8.4 HIAC1D
8.5 SPANDAR
8.6 RAPP
8.7 RAIN

PROGRAM KNOLL1D

DECK SETUP (OBJECT FILE)

CONTROL CARDS

```
JOBNR,CM110000,T900,TPN.*               Prob. No.     Name

ATTACH,LGO,KNOLL1DBINX2876,ID=GLASS,MR=1.

ATTACH,A10,A10FORMAT.

REQUEST TAPE1,S,HI,VSN=PMSXXX.

REQUEST TAPE2,RING,VSN=TAPENO.

REQUEST TAPE7,RING,VSN=TAPENO.

FILE (TAPE1,RT=U,BT=K,MRL=1024,MBL=1024,RB=1,BFS=105)

LDSET,FILES=TAPE1,PRESET=ZERO.

MAP,OFF.

LOAD,A10.

LGO.

REWIND,TAPE3,TAPE8.

COPY,TAPE3.

COPY,TAPE8.

EXIT.

REWIND,TAPE3,TAPE8.

COPY,TAPE3.

COPY,TAPE8.

7/8/9

DATA CARDS

7/8/9

6/7/8/9
```

*N = Number of REQUEST TAPE cards (i.e. 1,2, or 3)
for Plottape option must have REQUEST TAPE2 card
for Rapptape option must have REQUEST TAPE7 card

DATA CARD SEQUENCE SUMMARY

A. REQUIRED DATA CARDS

card #'s	
1-4	coefficient/exponent cards
5	start/stop processing time
6	tape card
7	flight information card
8	option card

B. OPTIONAL DATA CARDS

(9-18) max	JVCO cards	(OPTIONAL-only if card 8 cc 34-35 is greater than zero)
(19-38) max	RADIOSONDE cards	(OPTIONAL-only if card 8 cc 30 is two)
(39-43) max	EDIT cards	(OPTIONAL)
(44-58) max	TYPE cards	(OPTIONAL)

TYPE and EDIT cards may be intermixed

COEFFICIENT/EXPONENT CARDS

The four cards \$DCOEF, \$PCOEX, \$SCOEF and \$VCOEF are used to change: the adjusted class coefficients (with their breakpoints); equivalent melted diameter coefficients and exponents (with their breakpoints); sounding coefficients; and VCO coefficients.

The breakpoints allow the coefficients or exponents for a given particle type to be changed as the channel number or crystal size gets larger. BRKPTN controls the coefficients of the adjusted class equation; the units are in N (channel number). BRKPTC controls the coefficients and exponents of the equivalent melted diameter equation; the units are in mm (crystal size).

The particle type code is shown as follows:

J	Type
1	RAIN
3	WET SNOW
5	LARGE SNOW
7	SMALL SNOW
9	BULLET-ROSETTES
11	COLUMNS
13	NEEDLES
15	RMC EXPERIMENT #1
17	RMC EXPERIMENT #2
19	UNUSED AT THIS TIME

1. $DCOEF card

This card allows the coefficients of the adjusted class equation

$$N' = mN + b \qquad \text{where } N = \text{measured class}$$

to be changed. The breakpoints for this equation are also changed using this card.

Control variables: MB(I,J), BRKPTN(J)
where: I = 1 or 2 and J = 1 to 9

I = 1 for the slope (m)
I = 2 for the intercept (b)
J = particle type code ($N \leq$ breakpoint)
J+1 = particle type code ($N >$ breakpoint)

For example, to set the slope for type rain equal to 1.0 for classes 1 through 3 and equal to 1.5 for classes 4 through 15 use:

```
@$DCOEF MB(1,1)=1.0,MB(1,2)=1.5,BRKPTN(1)=3,BRKPT(2)=3 $END
```

NOTE: This breakpoint is probe independent i.e. the breakpoint occurs twice, once for the cloud probe and once for the precip probe.

2. $PCOEX card

This card allows the coefficients and exponents of the equivalent melted diameter equation

$$D = co(d^{ex}) \qquad \text{where } d = \text{crystal size in mm}$$

to be changed. The breakpoints for this equation are also changed using this card.

Control variables: COEX(I,J),BRKPTC(J)
where I = 1 or 2 and J = 1 to 9

I = 1 for the coefficient (co)
I = 2 for the exponent (ex)
J = particle type code ($d \leq$ breakpoint)
J+1 = particle type code ($d >$ breakpoint)

For example, to set the exponent for type Small Snow equal to 1.5 for crystal sizes less than or equal to .4 mm and equal to 2.0 for crystals sizes greater than .4 mm use:

```
@$PCOEX COEX(2,7)=1.5,COEX(2,8)=2.0,BRKPTC(7)=BRKPTC(8)=0.4 $END
```

NOTE: This breakpoint is probe dependent i.e. the breakpoint occurs only once regardless of the probe being used.

3. $SCOEF card

This card allows the coefficients of the pressure-height sounding equation to be changed.

Control variable: S(I)

where I = 1 to 5

I	
1	first order coefficient
2	second order coefficient
3	third order coefficient
4	fourth order coefficient
5	fifth order coefficient

For example, to change the second order coefficient, the control variable is S(2) = new value.

4. $VCOEF card

This card allows the VCO calibration coefficients to be input. The default coefficients are 0,1 and 0. Thus each run must have the desired coefficients input.

Control variable: C(I,J)

where I = 1 to 3 and J = 1,13 for A Model

J = 1,7 for E Model

I		J	A MOD	E MOD
1	intercept	1	pressure	delta-p
2	slope	2	delta-p	temperature
3	third order coef.	3	heading	pressure (msb)
		4	temperature	pressure (lsb)
		5	event and cloud	dewpoint (1011)
		6	LWC-JW	LWC-JW
		7	rain spectrometer	heading
		8	Tacan bearing	
		9	Tacan distance	
		10	acceleration	
		11	dewpoint (1011)	
		12	icing rate meter	
		13	pitch	

For example, to input the third order coefficient of JW, the control variable is C(3,6) = value.

5. Start & stop processing card

These variables control the data to be processed; any time prior to the start time or after the stop time is ignored.

cc	1-6	START=
cc	7-16	@HH:MM:SS@
cc	17-20	blank
cc	21-25	STOP=
cc	26-35	@HH:MM:SS@

6. Tape card

This card contains the input and output tape numbers. If desired it may be left blank.

cc	1-6	INPUT TAPE NUMBER
cc	7-10	blank
cc	11-16	PLOT TAPE NUMBER
cc	17-20	blank
cc	21-26	RAPP TAPE NUMBER

7. Flight information card

cc	1-10	Flight Id	FLT@XYR-NN
		where:	X must be aircraft model i.e. A or E
			YR is the last 2 digits of the year
			NN is the flight number
cc	11-20	Flight Date	@DD@MON@YR
		where:	DD is the day of the month
			MON is the first three letters of the month
			YR is the last 2 digits of the year
cc	21-24	blank	
cc	25-30	PMS on Time	HHMMSS
		where:	HHMMSS is the time corresponding to PMS count of 0000

8. Option card

This card specifies the options to be used. It also causes certain optional cards to be required.

cc 5	ICRYS	= 1	TYPING BY TEMPERATURE
		= 2	UNUSED
		= 3	TYPING BY MANUAL INPUT
cc 10	ICLK	= 1	TIME FROM AIRCRAFT CLOCK
		= 2	TIME FROM PMS BUFFER
cc 15	IDAT	= 0	PRELIMINARY DATA
		> 0	FINAL DATA
cc 20	IPLT	= 0	PLOT TAPE NOT PRODUCED
		= 1	PLOT TAPE PRODUCED
cc 22-25	INTA	= 0	FULL DATA
		> 0	AVERAGING INTERVAL IN SECONDS
cc 30	ITMP	= 0	TEMPERATURE DETERMINATION BY VCO
		= 1	DETERMINATION BY STANDARD ATMOSPHERE
		= 2	TEMPERATURE DETERMINATION BY RADIOSONDE PROFILE
cc 35	JVCO	= 0	CALCULATE VCO PARAMETERS
		> 0	NUMBER OF JVCO CARDS
cc 40	NSKP	= 0	PROCESS FIRST FILE
		> 0	NUMBER OF FILES TO SKIP BEFORE PROCESSING
cc 45	IDEK	= 0	DECK NOT PUNCHED
		= 1	DECK PUNCHED
cc 50	IRAD	= 0	RAPP TAPE NOT PRODUCED
		= 1	RAPP TAPE PRODUCED
cc 55	KWAJ	= 0	STANDARD PROBE CONFIGURATION
		= 1	KWAJALEIN PROBE CONFIGURATION

Option card (cont'd)

NOTES

1. ICRYS

   For ICRYS=3 at least 1 TYPE card is required

2. ICLK

   For ICLK=1 PMS on time may be set to zero

3. IDAT

   For IDAT>0 IDAT is printed as FINAL # on page 2 of output

4. ITMP

   For ITMP=1 Standard atmosphere equation is:

   $$T = 76.88288(P)^{0.190284}$$

   For ITMP=2 Profile uses a maximum of 20 levels

5. JVCO

   For JVCO>0 allows VCO parameters to be manually input for specified time. This option overrides the ITMP selection

9-18 (max) JVCO cards (optional)

JVCO cards are required only if cc 34-35 on the option card is greater than zero. These cards override the VCO calculations; they supply the basic meteorological parameters necessary for processing. The input values are constant for the duration of the time specified. The card format follows

cc	FORMAT	DESCRIPTION	
1-10	A10	@HH:MM:SS@ interval start time	
11-20	A10	@HH:MM:SS@ interval stop time	
21-30	F10.0	PRESSURE (mb)	free field with decimal point
31-40	F10.0	AIRSPEED (knots)	
41-50	F10.0	TEMPERATURE (°C)	
51-60	F10.0	HEIGHT (feet)	

19-38 (max)   RADIOSONDE cards (optional)

These cards are required only if the option card cc 30 is 2. They override the VCO temperature calculation by allowing the temperature to be determined by linear interpolation using the RADIOSONDE temperature-pressure profile. The first card contains the number of cards to follow (20 maximum). The remaining cards contain the RADIOSONDE profile. These cards <u>must</u> be in descending pressure sequence.

card 1

cc	1-2	number of levels

cards 2...n

cc	1-10	PRESSURE (mb)
cc	11-20	TEMPERATURE (°C)

39-43 (max) EDIT cards (optional)

These cards allow selected particle channel counts to be edited. The current editing constraints are as follows:

To edit channel 1 or 15 - there must be two valid channels on one side

To edit channels 2-14 - there must be one valid channel on both sides

To edit channels 1 and 2- there must be a valid channel 3

cc	FORMAT	DESCRIPTION
1-4	A4	EDIT
5-14	A10	START TIME (@HR:MN:SC@)
15-24	A10	STOP TIME (@HR:MN:SC@)
25-26	I2	PROBE NO. 1 = scatter
27-28	I2	PROBE NO. 2 = cloud
29-30	I2	PROBE NO. 3 = precip
31-33	I3	CHANNEL NO.
34-36	I3	CHANNEL NO.
37-39	I3	CHANNEL NO.
40-42	I3	CHANNEL NO.
43-45	I3	CHANNEL NO.
46-48	I3	CHANNEL NO.
49-51	I3	CHANNEL NO.
52-54	I3	CHANNEL NO.

44-58 (max) TYPE cards (optional)

The type cards are required only if the option card cc 5 is 3. These cards specify the particle type to be used for the selected interval. The cloud probe type and precip probe type may be different. The scatter probe is always type rain.

TYPE CARDS

cc	FORMAT	DESCRIPTION
1-4	A4	TYPE
5-14	A10	START TIME (@HR:MN:SC@)
15-24	A10	STOP TIME (@HR:MN:SC@)
25-26	I2	TYPE KEY (Cloud Probe)
27-28	I2	TYPE KEY (Precip Probe)

TYPE KEY

1	RAIN
3	WET SNOW
5	LARGE SNOW
7	SMALL SNOW
9	BULLET-ROSETTES
11	COLUMNS (4:1)
13	NEEDLES (7.5:1)
15	RMC 1-EXPERIMENTAL
17	RMC 2-EXPERIMENTAL
19	UNUSED AT THIS TIME

NOTE: The TYPE/EDIT cards are interchangeable and can be in any order. There is a maximum of 15 TYPE cards and 5 EDIT cards, any more will be ignored.

KNOLL1D v2.01

1. For upper altitude pressures (P < 440mb) the following pressure correction is applied ...

$$P_{COR} = 1.25^{*}P_i - 110$$

where

P_{COR} = corrected Pressure

P_i = calculated Pressure

2. For a/c time between 12:07:08 & 12:48:53 use

$\Delta P = 37.06$mb FIXED

NOTE - this version is for flight A75-19 only(15 APR 75)

OPERATING CHANGES

1. control cards:

   use cycle = 201

2. data cards:

   none

KNOLL1D v2.02

1. Height calculated from interpolation of time-height profile

2. Pressure calculated from ...

$$P = P_0 \left(1 - \left(\frac{a}{T_0}\right) HT\right)^{1/aR}$$

where

P_0 = Pressure @ ground
T_0 = Temperature @ ground
a = Lapse rate @ ground
R = Gas constant
HT = Height

OPERATING CHANGES

1. control cards:
   use cycle = 202
2. data cards:
   insert immediately after option card

1st card:

cc	description
1-2 (rj)	# of levels to follow
11-20(ff)	P_0
21-30(ff)	T_0
31-40(ff)	a
41-50(ff)	R

rj = right justified
ff = free field with decimal point

remaining cards:
(50 max)

cc	description
1-10	time@HH:MM:SS@
11-20(ff)	height (meters)

NOTE:

1. start time must be greater than or equal to the time of level 1
2. stop time must be less than or equal to the time of the last level

KNOLL1D v2.03

1. For Precip Probe, type 2 only, the breakpoint occurs at $N \geq 5$ instead of $N \geq 3$. Other changes for this probe are done with data cards.

2. The Cloud Probe changes are also done with data cards.

NOTE - This version was created from 2.01. It should be used with flight A75-19 only (15 APR 75)

OPERATING CHANGES

1. control cards:

   use cycle 203

2. data cards

```
@$DCOEF
@MB(1,2)=0.475,MB(2,2)=3.53,
@MB(1,3)=1.170,MB(2,3)=0.0,
@MB(1,6)=1.170,MB(2,6)=0.0,
@BRKPT(2)=1.755,BRKPT(3)=1.755,
@$END
@$PCOEX
@COEX(1,2)=0.370,COEX(2,2)=0.670,
@COEX(1,3)=0.370,COEX(2,3)=0.670,
@$END
```

KNOLL1D v2.04

1. This version incorporates the latest changes requested by Dr. R. M. Cunningham through 24 NOV 75.

2. The particle type list has been expanded. Refer to the operating instructions (page 8) for a complete list of particle types.

3. The breakpoint option has been modified to include two types of breakpoints: crystal size and channel number. Pages 5 and 5.1 of the operating instructions reflect these changes.

NOTE - This version was created from 2.03. It should be used with flight A75-19 only.

OPERATING CHANGES

1. control cards:

   use cycle = 204

2. data cards:

   $DCOEF see operating instructions for card 1
   TYPE CARD see new particle type key

KNOLL1D v2.05

1. This version is the standard for all flights before December 1975, except 15 APR 75. It incorporates all the changes of v2.04.

OPERATING CHANGES

1. control cards:

   use cycle 205

2. data cards:

   none

KNOLL1D v2.06

1. This version is the standard for all flights after December 1975.

2. It should be used with all PMS tapes with the new format. The tape format changes are summarized below:

WORD#	NEW	OLD
1	elapsed time	sync
17	B0 status word	probe configuration
33	C0 status word	elapsed time
49	D0 status word	unused

OPERATING CHANGES

1. control changes:

   use cycle = 206

2. data cards:

   none

KNOLL1D v2.07

1. This version contains changes to data modification routine used in v2.06. These changes, primarily for processing the data from flight A76-04 on 11 February 1976, include the following:

   A. Data modification is not used for particle types RAIN or WET SNOW.

   B. If there are insufficient points from the precip probe (i.e. less than two channels) the data modification technique is not used. However, the cloud-precip gap is still eliminated and M, Z, D_o and K are recalculated. The gap elimination technique has not been changed. Refer to the KNOLL1D Operating Manual for a complete description of this technique.

OPERATING CHANGES

1. control cards:
   use cycle = 207

2. data cards:
   none

KNOLL1D v2.08

1. This version utilizes the data modification routine from v2.07 and the pressure correction routine from v2.02.

2. The height is determined by interpolation of the time-height profile.

3. The pressure is calculated from:

$$P = P_0(1-(\frac{a}{T_0})HT)^{1/aR}$$

where:

P_0 = pressure @ ground
T_0 = temperature @ ground
a = lapse rate @ ground
R = gas constant
HT = height

OPEARATING CHANGES

1. control cards:
   use cycle = 208

2. data cards:
   insert immediately after option card

1st card:

cc	description
1-2 (rj)	# of levels to follow
11-20(ff)	P_0
21-30(ff)	T_0
31-40(ff)	a
41-50(ff)	R

rj = right justified
ff = free field with decimal point

remaining cards:

(50 max)	cc	description
	1-10	time @HH:MM:SS@
	11-20(ff)	height (meters)

@ = blank

NOTE:

1. start time must be greater than or equal to the time of level 1

2. stop time must be less than or equal to the time of the last level

KNOLL1D v2.09

1. This version will produce a line printer plot of total D_0, M, and Z as a function of time. The three variables are plotted on the same logarithmic scale with a range of ± 4.0

2. The output deck format has been changed to the following:

cc	variable	
1	blank	
2-7	time (HHMMSS)	
8-10	blank	
11-15	height (feet)	
21-30	LWC scatter	gm/M^3
31-40	LWC cloud	gm/M^3
41-50	LWC precip	gm/M^3
51-60	D_0 cloud	microns
61-70	D_0 precip	microns
71-80	D_0 total	microns

3. The timing and central memory requirements have been reduced considerably. This should improve program turn around time.

OPERATING CHANGES

1. control cards:
   a. job card requires CM61000 and a time limit of 150 seconds per hour of data.
   b. use cycle 209
   c. for the line printer plot add the following cards after the LGO.

      REWIND,TAPE9.
      COPY,TAPE9.
2. data cards
   option card col 65 = 1 to produce the line printer plot

8.2 KNPLT1D

CONTROL CARDS

```
JOBNR,CM160000,T500,TP1.        Prob. No.       Name
REQUEST TAPE2,VSN=_ _ _ _ _ _.¹
ATTACH,LGO,KNPLT1DBINX2876,ID=GLASS,CY=_ _,MR=1.
ATTACH,CRT,OFFLINECRT,MR=1.
DISPOSE,TAPE39,*FL.
LIBRARY,CRT.
LDSET,PRESET=ZERO.
LGO.
7/8/9
DATA CARDS
7/8/9
6/7/8/9
```

[1]IF THE LEARJET TAPE IS TO BE PLOTTED THIS CARD MUST BE...

REQUEST TAPE1,VSN=_ _ _ _ _ _.

DATA CARDS

The first data card is the information card; it appears only once. The format for this card is shown below.

Each plot type requires a plot request card. These request cards are unlimited and have the same format. The cards are divided into 16 fields. Each plot type requires certain fields to be used; all the unused fields may be left blank.

card 1. information card

VAR	cc	FORMAT	FUNCTION
PLT	1-3	A3	plot type: PEN or CRT
CLK	5	I1	clock: 1=A/C 2=PMS
IOUT	7	I1	0 = summary only 1 = data & summary
FLID	11-20	A10	flight id: FLT XYR-NN
	21-30	A10	date: DD MON YR
OPT	45	I1	0 = standard data 1 = Learjet data
INT	49-50	I2	averaging interval (OPT = 1 only)

cards 2...n plot request cards

cc	FORMAT	FUNCTION
1	I1	field 1
3	I1	field 2
5-10	I6	field 3
15-20	I6	field 4
22-25	I4	field 5
27-30	I4	field 6
32-35	I4	field 7
37-40	I4	field 8
42-45	I4	field 9
47-50	I4	field 10
52-55	I4	field 11
57-60	I4	field 12
62-65	I4	field 13
67-70	I4	field 14
72-75	I4	field 15
77-80	I4	field 16

Cards 2 through n may appear in any sequence, however, considerable time is saved if cards with same time limits are consecutive.

The following page,"Request card summary" shows the required fields for each plot type.

REQUEST CARD SUMMARY

FIELD	cc	SCATTER	MZHIST	VCOHIST	SPECTRA	DO	VCOPLOT
1	1	1	2	3	4	5	6
2	3				probe		number
3	5-10	start	start	start	start	start	start
4	15-20	stop	dur	dur	stop	stop	stop
5	22-25	pass	pass		min }bl	pass	h axis code
6	27-30	htkm	htkm		max }bl	htkm	v axis code
7	32-35	min lwc	min lwc		min }br	min lwc	type code
8	37-40	exp	exp		max }br	exp	h axis code
9	42-45				min }ml		v axis code
10	47-50				max }ml		type code
11	52055				min }mr		h axis code
12	57-60				max }mr		v axis code
13	62-65				min }tl		type code
14	67-70				max }tl		h axis code
15	72-75				min }tr		v axis code
16	77-80				max }tr		type code

start = start time (hhmmss)
stop = stop time (hhmmss)
dur = duration in seconds
pass = pass number
htkm = height (km)·10
i.e. 6.5 km = 65
probe = 1; scatter

probe = 2; cloud
probe = 3; precip
number = number of plots (max=4)
min, max = LWC limits
bl, br = bottom left, bottom right
ml, mr = middle left, middle right
tl, tr = top left, top right

AXIS and type codes are shown on the next page

AXIS & TYPE CODES

The following axis and type codes must be used for the VCO plot request card.

AXIS CODE

1	Pressure
2	Height
3	Temperature
4	Dewpoint
5	LWC-JW
6	LWC-AUSSIE
7	Icing Rate
8	Tacan Bearing
9	Tacan Distance
10	Magnetic Heading
11	Velocity
12	Pitch
13	Accelerometer
14	LWC Scatter
15	LWC Cloud
16	LWC Precip
17	LWC Total
18	log Z Scatter
19	log Z Cloud
20	log Z Precip
21	log Z Total

TYPE CODE

1	Scatter Plot
2	Line Plot

JW-LWC adjustment card

If a VCO plot request card specifies a LWC-JW vs HEIGHT plot, (i.e. h axis code = 5, v axis code = 2, and type code = 0) the next card must contain the adjustment parameters. The required parameters are:

L = number of levels (10 maximum)
XJ = origin of the level
SL = slope of the level
HT = height (meters) at the top of the level

The card uses a standard namelist format with the control variable being $ADJUST. If the option is not desired the card must be

$ADJUST L=0, $END

8.3 KN1UTIL KNOLLENBERG TAPE UTILITY PROGRAM OPERATING INSTRUCTIONS

CONTROL CARDS

```
JOBID,CM60000,T100,TP2.*          Prob No.       Name
VSN,TAPE1=TAPENO,TAPE2=TAPENOIN.
FTN,PL=999999,SL,R=3,P.
REQUEST,TAPE1,S,HI.
REQUEST,TAPE2,S,HI.
FILE(TAPE1,RT=U,BT=K,MRL=1024,MBL=1024,RB=1,BFS=105)
LDSET,FILES=TAPE1,PRESET=ZERO.
MAP,OFF.
LGO.
REWIND,BPARAM,CPARAM,DPARAM.**
COPY,BPARAM.**
COPY,CPARAM.**
COPY,DPARAM.**
7/8/9
SOURCE DECK
7/8/9
DATA DECK
7/8/9
6/7/8/9
```

*If not duplicating a tape

1. change TP2 to TP1
2. remove TAPE2=TAPENOIN from VSN card
3. remove REQUEST TAPE2 card

**Remove the cards if status word dump is not desired

OPTIONS

1. Decimal Dump - one data card

cc 2-4	DEC
cc 5-7	number of files dumped
cc 8-10	record indicator
	i.e. 1 = every record
	2 = every other record
	6 = every sixth record

ex. to dump decimally, two files every 10th record

-DEC--2-10 - = blank

2. Octal Dump - one data card

cc 2-4	OCT
cc 5-7	same as decimal dump
cc 8-10	

ex. to dump octally, nine files every 100th record

-OCT--9100 - = blank

3. Selective Record Dump - n data cards (Decimal only)

card 1

cc 2-4	REC
cc 5-7(rj)	number of files dumped
cc 8-10(rj)	record indicator

cards 2...n (one card for each set of records)

cc 1-6(rj)	starting record to dump
cc 7-12(rj)	ending record to dump

ex. to dump every 10th record
from 125 to 350 and
from 1000 to 1500

```
-REC--1-10

---125---350

--1000--1500          - = blank
```

4. Tape Copying - n data cards

card 1

cc 2-4	DUP
cc 5-7	number of files to copy

cards 2...n (one card for each file to be copied)

cc 1-6(rj)	number of record to skip before copying
cc 7-12(rj)	number of records to copy

ex. to create a tape of:
records 701 to 750 from file 1,
and records 25 to 50 from file 3,
the data deck is ...

```
-DUP--3
---700----50
-----0-----0
----24----26          - = blank.
```

5. Selective Probe Dump (1 data card)

cc 2-4	DEC
cc 5-7	number of files dumped
cc 8-10	record indicator
	i.e. 1 = every record
	2 = every other record
	6 = every sixth record
cc 15	selected probe

BLANK/0 for regular decimal dump (OPTION 1)
1 for scatter probe only
2 for cloud probe only
3 for precip probe only

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CONTINUATION OF DEVELOPMENT AND APPLICATION OF DATA PROCESSING --ETC(U)
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UNCLASSIFIED AFGL-TR-76-0182 NL

3 OF 3
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END
DATE
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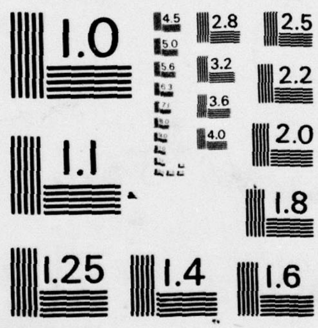
2-77



MICROCOPY RESOLUTION TEST CHART

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ex. To dump decimally, 2 files every 10th record for Precip Probe

```
-DEC--2-10----3        - = blank
```

8.4 HIAC1D

The MRI1D program has been rewritten to process the High Altitude aircraft tapes. The program will list the tapes in a format similar to KNOLL1D. HIAC1D uses the standard (210 words/record) tape as input. The program will produce an output tape suitable for processing with program RAPP (9 words/record).

An editing option is included to eliminate certain channels. Actually the channels specified are zeroed out.

The median volume diameter is also calculated for the three probes.

CONTROL CARDS

```
JOBNR,CM60000,T200,TP1.
REQUEST TAPE1,VSN=_______.
REQUEST TAPE2,VSN=_______,RING.
ATTACH LGO,HIAC1DBINX2876,ID=GLASS,MR=1.
ATTACH A10,A10FORMAT.
MAP,OFF.
LOAD,A10.
LGO.
REWIND,TAPE3.
COPY,TAPE3.
EXIT,S.
REWIND,TAPE3.
COPY,TAPE3.
6/7/8/9
```

INPUT CARDS

Card 1	col.	1-6	input tape number
Cards 2-n			(one card per pass)
	col.	1-10	start time HH:MM:SS
		11-20	stop time HH:MM:SS
		21-25	pass number
		26-30	averaging interval (seconds)
		33	1st probe to be edited
		34	2nd " " " "
		35	3rd " " " "
		37-38	1st channel to be edited
		40-41	2nd " " " "
		43-44	3rd " " " "
		46-47	4th " " " "
		49-51	5th " " " "
		52-53	6th " " " "
		55-56	7th " " " "
		58-59	8th " " " "
		61-62	9th " " " "
		64-65	10th " " " "
		67-68	11th " " " "
		70-71	12th " " " "
		73-74	13th " " " "
		76-77	14th " " " "
		79-80	15th " " " "

8.5 SPANDAR OPERATING INSTRUCTIONS

There are no data cards required to run this program. Every run will produce an output tape with a tape summary.

CONTROL CARDS

```
JOBNR,CM65000,T100,TP2.                   Prob No.          Name
REQUEST TAPE1,L,VSN=TAPENO.
REQUEST TAPE3,RING,VSN=LYCXXX.
ATTACH LGO,SPANDARBINX2876,ID=GLASS,MR=1.
FILE,TAPE1,RT=U,BT=K,MRL=5339,MBL=5339,RB=1,BFS=536.
MAP,PART.
LDSET,FILES=TAPE1,PRESET=ZERO.
LGO.
REWIND,TAPE8.       } required for tape listing only
COPY,TAPE8.         }
REWIND,TAPE2.       } required for line printer plot only
COPY,TAPE2.         }
REWIND,TAPE4.       } required for punched deck only
COPYCF,TAPE4,PUNCH. }
6/7/8/9
```

8.6 RAPP

```
GLAR4, CM75000, T200,TP2.        2014        GLASS
REQUEST,TAPE1,VSN=LYCXXX.         (KNOLL1D OUTPUT TAPE)
REQUEST,TAPE3,VSN=LYCYYY.         (SPANDAR OUTPUT TAPE)
ATTACH,LGO,RAPPBINX2876,ID=GLASS,MR=1.
ATTACH,CRT,OFFLINECRT,MR=1.
DISPOSE,TAPE39,*FL.
LIBRARY(CRT)
LDSET,PRESET=ZERO.
LGO.
7/8/9
DATA
6/7/8/9
```

CARD 1	HEADER CARD
cc 1-6:	MISSION ID XYR-NN (A6)
cc 8-13:	A/C TYPE C130-E or C130-A (A6)
cc 15-24:	FLIGHT DATE DD@MON@YR (A6)
cc 25:	PROBE 1=SCATTER,2=CLOUD,3=PRECIP,4=TOTAL (I1)
cc 31-40:	RADAR OFFSET DISTANCE (IN METERS)(F10.0)
cc 41-50:	RADAR CORRECTION (IN DB)(F10.0)
cc 55:	KWAJ (1=IF KWAJALEIN FLIGHT,0=OTHERWISE)(I1)
cc 56-65:	DB1 (MINIMUM RADAR DETECTABLE CONSTANT)(F10.0)

CARDS 2-N+1	PASS CARDS FOR N PASSES
cc 1-2:	PASS NUBMER (I2)
cc 4-9:	BEGINNING PASS TIME IN HHMMSS (F6.0)
cc 11-16:	ENDING PASS TIME IN HHMMSS (F6.0)
cc 17:	CRYSTAL TYPE I=ICE, W=WATER(RAIN)(A1)
cc 20-29:	MINIMUM LWC VALUE (gm/M)(F10.0)

8.7 RAIN PROGRAM RAIN

CONTROL CARDS

```
JOBNM,CM70000,TP1,T300.        2014        GLASS
ATTACH,LGO,RAINBINX2876,ID=GLASS,MR=1.
REQUEST,TAPE1,S,VSN=TAPENO.
ATTACH,CRT,OFFLINECRT,MR=1.
DISPOSE,TAPE39,*FL.
FILE(TAPE1,RT=U,BT=K,MRL=104,MBL=104,RB=1,BFS=13)
LIBRARY,CRT.
LDSET,FILES=TAPE1,PRESET=ZERO.
LGO.
7/8/9
DATA CARDS
6/7/8/9
```

DATA CARDS

CARD 1	HEADER CARD
cc 1-2:	GROUPING INTERVAL (SECONDS) (USUALLY 10)
cc 4-13:	DATE DD@MON@YR @ = blank
CARD 2-(F+1)	F = NUMBER OF FILES ON TAPE
cc 1-6:	FILE START TIME (OCTAL) HHMMSS
cc 10-15:	(K) NUMBER OF SIGNIFICANT BITS (I5)(rj)
cc 20-25:	(F) RANGE SWITCH SETTING OF PEAK LOAD VOLTMETER (rj)

rj = right justified